RS FOUNDATION FOR MARINE RESEARCH
ham Oceanographic Laboratory, Yale University

Journal of Marine Research

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Note to Subscribers, Authors and Associate Editors

istory. For many years prior to 1937, Professor Albert E. Parr, then ctor of the Bingham Oceanographic Foundation, felt that there was a ct need in this country for a publication that would serve as a vehicle ort articles on "marine biology and oceanography". In 1937 these aspira- were realized with establishment of the Sears Foundation through ous gifts from Mr. Henry Sears. The primary function of the Sears dation, then as now, has been publication of the Journal of Marine arch and Memoirs of the Sears Foundation.

ne Journal of Marine Research is an outlet for short articles, occasionally nger ones, dealing with any aspect of scientific marine investigation having ect or indirect bearing on problems of the sea, excepting only papers on natics[1]. Thus it is intended that the Journal of Marine Research dis- ate information pertaining to all subjects related to the ocean. In serving arious branches of oceanography, the Journal advances all areas by ac- ting those in one area with problems and developments in the numerous areas. Generally the Journal of Marine Research publishes articles that ither theoretical or descriptive.

hile this publication is intended primarily to serve the needs of Oceano- y in North America, its pages are open to contributors from all countries. ractical purposes, all papers are published in English only, and a foreign r should so prepare his paper.

[1] While such papers are also essential in advancing oceanography, it is felt that there are already nt outlets in specialized journals and institutional publications to handle them. Furthermore, rs of the Sears Foundation, of which two parts have been published, deals extensively with the atics of fishes.

Papers are generally submitted directly to the Editor, but they may also directed to a member of the Editorial Board. The Sears Foundation for Ma Research, Yale University, as in the past, continues to be closely associa with, though separate from, the Bingham Oceanographic Foundation. Sears Foundation offices are in the same building as the Bingham Ocea graphic Laboratory and the Editor's salary is paid by the latter departm

Through Volume 17, slightly less than 44% of the cost of publishing (excluding all overhead) has been financed by sales. The balance, somew more than 56%, has come from gifts from Mr. Henry Sears, from institut and individuals for special issues, and from miscellaneous repayments.

The Journal of Marine Research is available by subscription only, not exchange. To this general rule there are but few exceptions, usually m at the discretion of the Editor or his associates. In a number of instances Bingham Laboratory pays for certain subscriptions to obtain desired publicat in exchange for its library.

The Journal of Marine Research is widely distributed throughout the w although its subscription list is by no means large. All back issues of the Jou of Marine Research have been and continue to be available, with the volu priced as follows: Volumes 1–12 at $ 3.00 per volume; Volumes 13–1 $ 5.00 per volume; Volume 17 and subsequent volumes at $ 7.00 per volu Postage is included in the subscription price. All volumes contain three n bers, excepting Volumes 1 and 14, which contain four numbers.

The 18 volumes that have been published to date contain a total of 5, pages and 452 articles dealing with subjects that span the entire rang oceanography. On three occasions, with financial aid from other institut and persons, special issues have been published. The Sverdrup 60th Anniver (Volume 7, No. 3); An Oceanographic Convocation (Volume 14, No. and recently the T. G. Thompson 70th Anniversary (Volume 17). T issues were prepared in collaboration with members of the following institut Scripps Institution of Oceanography; Woods Hole Oceanographic Institut The Office of Naval Research, The National Academy of Sciences; and University of Washington.

The original Editorial Board consisted of Albert E. Parr, Carl-G. Ros Harald U. Sverdrup, and Thomas G. Thompson. Subsequently additi members were invited to membership, and they included Columbus O'D Is Daniel Merriman, Roger Revelle, Walter Munk, Dale Leipper and Do Pritchard. Until 1942 Albert E. Parr served as Managing Editor, at w time he became chairman of the Editorial Board and transferred his duti Managing Editor to the present Editor.

Reorganization. For a number of years consideration has been given t organization of the Journal of Marine Research, and in the spring of this the present Editor requested the appointment by Yale University of an visory Committee to examine the policies of the Sears Foundation and to

n action as was deemed advisable and necessary to strengthen the Journal Marine Research and Memoirs and to obtain financial support for their lication. This Committee at present consists of Vaughan T. Bowen (Woods le Oceanographic Institution), Daniel Merriman (Bingham Oceanogra- c Laboratory), Dayton Carritt (Massachusetts Institute of Technology), es Mead (Museum of Comparative Zoology, Harvard), and the present tor.

At its first meeting this spring, unanimous approval was given to the proposal t the Editorial Board be expanded and that the membership rotate every ee years. The members of the present Editorial Board are listed on the de front cover of this issue. Each year five new members will be invited to ve; thus the composition of the Board will change from year to year. The anization of the Editorial Board is informal, and it shall consist of as many ors as is deemed advisable to achieve competent handling of manuscripts to obtain adequate subject, geographical and institutional representation. At this same meeting, unanimous approval was also given to the proposal t the Journal of Marine Research appear on a regular publication schedule. the future, three numbers per volume per year will appear on 15 March, July, and 15 November, and the issues will go to press 15 July, 15 No- ber and 15 March, respectively. Authors submitting well prepared and eptable manuscripts will have their papers printed and distributed in nine twelve months. Eight months must normally be allowed for the printing e; that is, from the time the papers are submitted to the printer until the e is distributed. Oftentimes proofs must be submitted to authors in foreign ntries, and such communication is time consuming. The Bianco Lunos trykkeri in Denmark will do the printing on a prescribed schedule will distribute the issues from there. This company has already printed lume 17 and Volume 18, Numbers 2 and 3.

Most persons who are familiar with the Journal will note also that its face been changed. The new designs were prepared by Lewis F. White in w York, and in the new format considerable economy is achieved. This n line with other efforts to obtain an attractive and satisfactory publication he lowest possible cost.

Editorial Policy. To achieve publication of papers on schedule at the earliest sible date following submission, a high degree of cooperation is essential ween editor, author and referee. However, prior to submitting his paper, author can enhance the prospects of early publication by careful preparation his manuscript. A "Note to Authors", giving suggestions that may aid , is published on the inside rear cover.

With the new schedule, only galley proofs will be submitted to the author, emphasis is placed on the importance of checking the proofs carefully for er printer or author errors and returning them promptly. A note regarding tment of his galley proofs will be submitted to an author with each set of

proofs. Failure of an author to return proofs by the date specified may ca delay of his publication.

An author is provided with 50 free reprints with covers up to a total 100 for two or more authors. These are shipped some time after the m issue is distributed. Authors and institutions may order additional repri either with or without covers, directly from the printer in Denmark. Ord should be addressed to the printer at the time the galleys are returned by author. Please specify to the printer whether or not covers are desired. If Journal of Marine Research cover is used, only charges for presswork a paper will be made against the author or institutions, but if a special cove required, then composition costs are also added. The printer's address is follows:

Bianco Lunos Bogtrykkeri
Otto Mønsteds Gade 3
Copenhagen V, Denmark.

Some of the members of the new Editorial Board have requested inf mation about their duties, and since the information may be of interest others, it is included here.

Each manuscript, whether it be the product of a member of the Edito Board or of a nonmember, is reviewed by other referees who are not associa with the institution from which the paper emanates. In short, each paper t is submitted for publication is accorded the same treatment. For the m part papers are refereed by Editorial Board members, but in some cases, referee may wish to obtain opinions from his colleagues to assist him in arrivi at a fair opinion. A referee's function in reviewing manuscripts is of paramo importance since the calibre of papers published depends in large measure his judgement. Thus the Journal's reputation is in his hands to a great exte

Each paper will be reviewed by two persons, and in the case of cont dictory opinions, by a third person. Such procedure, while more time consumi will assure an author of fair consideration.

Each issue will consist of the best manuscripts available. Those not selec will be returned to their authors who may submit them elsewhere, or requ they be considered for a following issue of the Journal of Marine Resear

If a paper is submitted directly to a member of the Editorial Board, Editor should be advised regarding the paper's status when it is forward that is, whether or not it has been read and whether or not it is accepta to the associate editor in its present form.

The referee, in forwarding his critique, is requested to submit it in duplic with his covering letter, if it is possible. Thus one copy is available for Editor's file, the other for the author.

In the case of controversial conclusions, it is especially important that Journal of Marine Research publish such contributions so long as they

hin the scope of this journal. In other words, such a paper should not be cted simply because of a referee's disagreement with the author. If it is especially provocative paper which may stimulate accelerated activity in the d, then it would indeed be unfortunate to withhold publication. The re- e, or anyone else, may publish a rebuttal either independently or in co- ration with the author.

An author is entitled to know why his paper is rejected, and it is important, efore, that a referee state clearly and concisely his reasons for rejection. author is quite justified in being annoyed if he is simply advised that his er is "not satisfactory for publication in its present state" or "is generally cceptable."

t is the responsibility of each referee to advise the Editor of any suggestions improving an author's presentation – for example, omission of a significant rence, poor organization and development of his thesis, ambiguity, in- ion of extraneous data and material, verbosity, poor organization of graphs ables, etc. In short, a paper should be so presented that readers of the Journal be given the desired information with the least expenditure of time and rt.

The referee may request anonymity, but he should not use it as a shield. he authors, particularly those who are inexperienced in writing, deserve aid encouragement provided the work warrants the time and attention. This ins also in the case of foreign authors who are handicapped by language iers. A sound and considered criticism can be very helpful to an author, for the most part authors are grateful for suggestions.

Each manuscript must be treated in the light of the reviewer's experience perspective. A policy that is too rigidly defined can defeat, in part at least, primary purpose of the Journal – dissemination of stimulating and creative k and thought.

With the cooperation and help of authors, editors and referees, and with tinued and increased support from subscribers, the Journal of Marine earch can and will continue its contributions to oceanography. Both finan- support and confidence are necessary to achieve the desired objective – iblication of uniformly high quality.

Yngve H. Olsen
Editor

November 1960.

Dissolved Nitrogen in West Greenland Waters[1]

D. C. Nutt[2], L. K. Coachman[3], and P. F. Scholander[4]

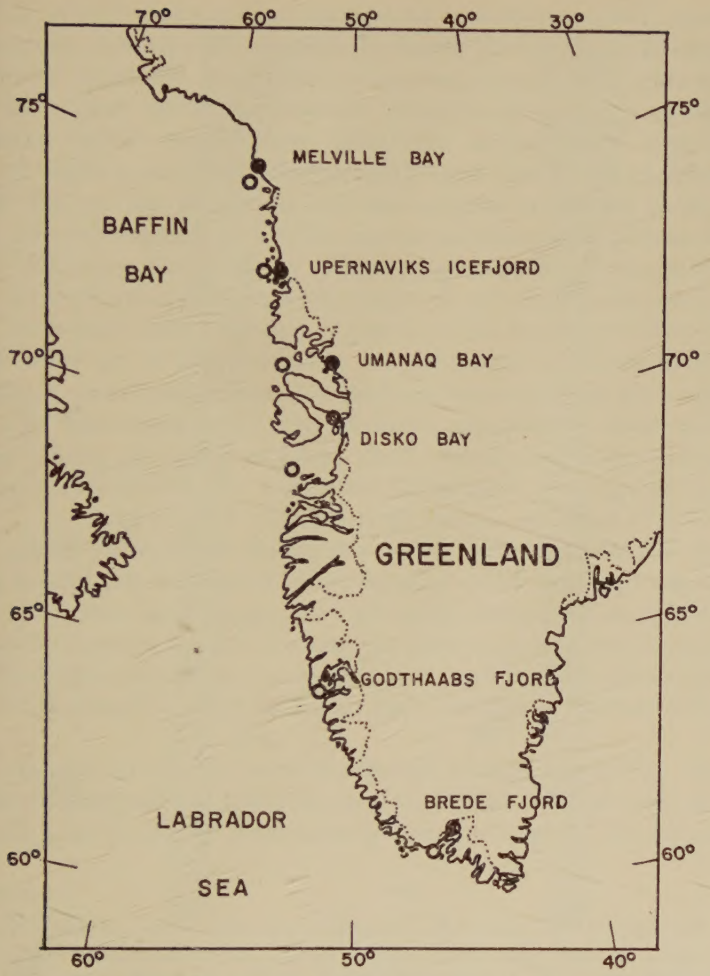
Abstract. The nitrogen tension in several water masses in the West Greenland coas region departs only about 5% from the value of the atmosphere. Significantly higher valu of nitrogen tension were found in the upper layers of waters near glacier fronts. These valu are attributed to the solution of gases trapped in the glacier ice and released to the wa under considerable hydrostatic pressure.

Introduction. It is generally assumed that all ocean water has at one tin been in contact with the atmosphere and that it became equilibrated at th time with the air at atmospheric pressure and under existing conditions temperature and salinity. Oxygen, because of its biological significance and ease of measurement, is extensively used as an index in the interpretation oceanographic and limnological phenomena; on the other hand, dissolved n trogen and other inert gases are seldom used, mainly because practical analytic methods are lacking. However, the oxygen content is subsequently altered biological and chemical processes whereas nitrogen, being essentially inert, assumed to be conservative and to remain unchanged. A knowledge of t nitrogen tension should give information concerning the degree of surfa equilibration and its maintenance. Rakestraw and Emmel (1938a), who su gested that a more exact calculation of the original oxygen content could obtained by taking nitrogen into account, determined dissolved nitrogen a argon at several North Atlantic stations. They showed that in 82 out of samples of sea water there was less than 5% variation from atmospheric nitr gen tension, although the temperature range extended from 26°C in the su face layers to 2.3°C at 4500 m depth. The argon values were also close saturation. Hamm and Thompson (1941) found much the same conditio for nitrogen in eastern Pacific waters.

The Arctic Institute Greenland Expedition in 1958 presented an opp tunity to extend our knowledge of nitrogen distribution to more northe

[1] This paper is based on work supported by the Arctic Institute of North America with funds p vided under contract with the U.S. Office of Naval Research. Reproduction in whole or in part is p mitted for any purpose of the U.S. Government.

[2] Dartmouth College. [3] University of Washington. [4] Scripps Institution of Oceanography



ure 1. Map of West Greenland showing location of oceanographic stations. Open circles indicate coastal stations, closed circles indicate ice front stations.

rs. Although the temperature ranges along the west coast of Greenland not as great as those in the Atlantic and Pacific studies noted, several masses of widely varying origin and life history were involved, and the nce of glacier fronts and floating ice presented interesting special con-ns. Pertinent data were obtained at selected stations along the west coast reenland from Melville Bay at 75°N Lat. to Brede Fjord at 61°N Lat. 1). Thus it was possible to observe: (1) the latitudinal distribution of ved nitrogen in coastal waters; and (2) the influence of glacier fronts loating icebergs on its amount.

Methods. Determinations of nitrogen saturation values require knowle of temperature, salinity and dissolved nitrogen. Temperature measurem were obtained from reversing thermometers or from BT traces controlled each cast by reversing thermometer observations. Water samples for sali and nitrogen determinations were taken with Nansen bottles. Salinity determined at the Woods Hole Oceanographic Institution either by sali meter, or, in the case of samples with low salinity, by the standard Knu titration method. Water samples for gas analysis were drawn from the Na bottles into ordinary 6-ounce glass salinity bottles which were filled to o flowing and sealed from the air under slight positive pressure; these sam were immediately stored in ice water to prevent bubble formation. In range of saturations encountered, the errors incurred in the open samp technique were in all instances less than 1%, and in most cases of near sa ation they were insignificant. Dissolved gases were determined by a mi gasometric method (Scholander, *et al.*, 1955) in which, for greater accur the water volume was measured by means of a 1-cc tuberculin syringe. A lyses, made in duplicate, usually agreed within ±0.15 ml/l.

There is some uncertainty in the calculation of saturation values, bec the nitrogen solubility values determined by Rakestraw and Emmel (19 differ from those determined earlier by Fox (1909). This uncertainty and limitations of our analytical accuracy preclude critical interpretations of saturation values obtained here, but at the same time they do not alter the b conclusions reached. Saturation values calculated by us are based on Fox's d

Results. There is a gradual decrease of about 7% in the quantity of solved nitrogen between Melville Bay in the north and Godthaab in the so (Fig. 2), but the nitrogen tension was consistently within ±5% of the atm

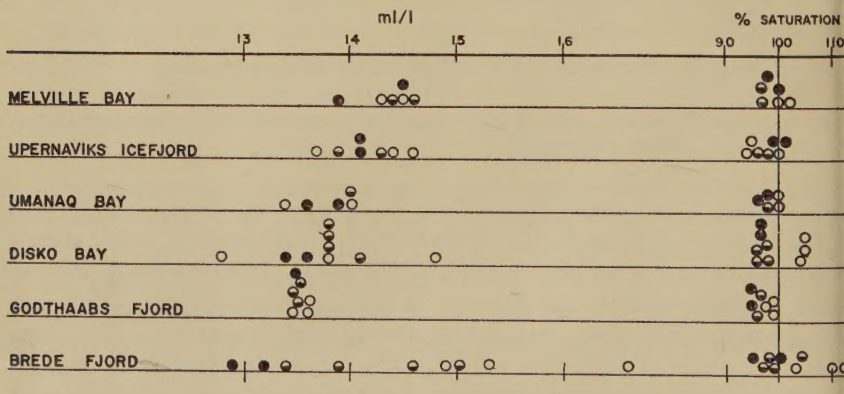
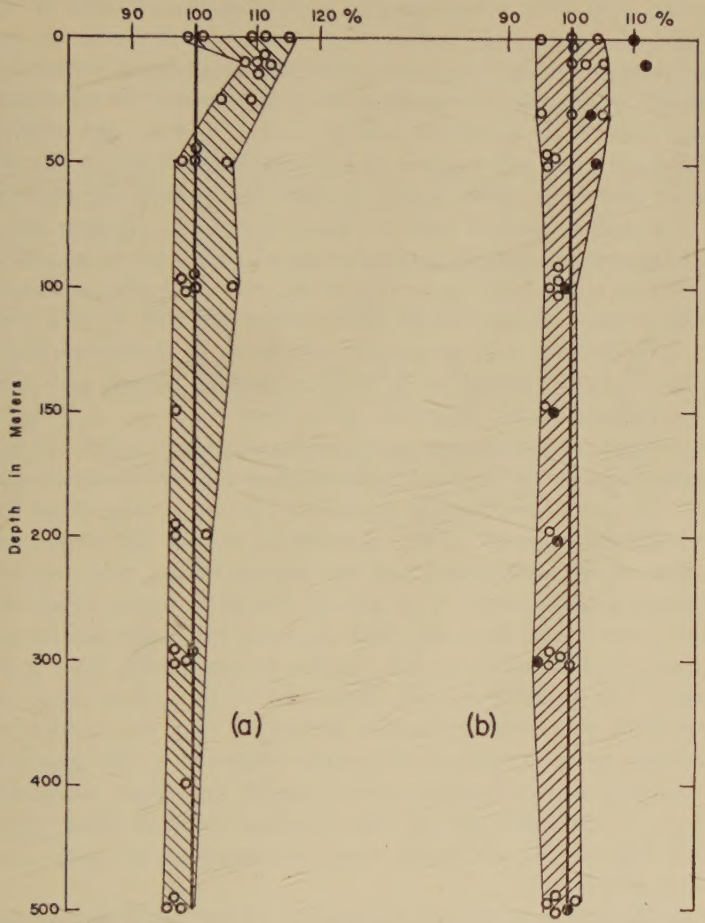


Figure 2. Plots of volumes of dissolved nitrogen and percent saturation obtained from coastal st in West Greenland. Open circles – values from depths of 0, 10, and 30 m; half solid c – values from depths of 50, 100, 150, and 200 m; closed circles – values from 300 and 5



ure 3. (a) represents the vertical distribution of percent saturation values for dissolved nitrogen observed at glacier front stations. (b) represents comparable distribution at coastal stations. The closed circles indicate values from Brede Fjord coastal station. For convenience the vertical scale is reduced below 200 m.

ic equilibration. In Brede Fjord this general north-south trend continued ıe lower levels while the upper levels were supersaturated.

he percent saturation values in a vertical profile from the glacier-front ons (Fig. 3a) and in a similar vertical profile from corresponding coastal ons (Fig. 3b) show that in the surface layers of all glacier-front stations is a measurable supersaturation of nitrogen amounting to some 5–10%. ıe deeper layers generally the water masses are nearly 100% saturated. ıe outer fjord stations (Fig. 3b) the water masses from all levels are sat-d, excepting the surface layers of Brede Fjord, which are supersaturated.

Discussion. The water masses sampled at the coastal stations in West Gre land consist of (1) a mixed surface layer warmed and freshened to vari degrees; (2) from 30 to 200 m, an intermediate layer of colder and m saline water, which, in Southwest Greenland, consists of remnants of East Greenland Polar Current; and (3) below 300 m, the deep layer warmer and still more saline water of Labrador Sea and Baffin Bay origin. the summer there is a stable density gradient throughout the water colu Except in a shallow surface layer of Brede Fjord the nitrogen tension essentially equal to that of the atmosphere at all depths in the coastal statio this equilibrium tension was apparently achieved at the surface and maintai in the water masses, even though their origin and past history were q different. This finding is in agreement with those of Rakestraw and Em (1938b) for Atlantic waters at 35°N Lat. and of Hamm and Thomp (1941) for eastern Pacific waters at 50°N Lat.

The nitrogen supersaturation observed in the upper layers of the gla front stations and in the surface water at Brede Fjord demands special planation. The ice of discharging glaciers and icebergs contains gas inclusi under considerable pressure. The composition of this gas is essentially same as that of the atmosphere, and the amount of gas, measured at atm pheric pressure, ranges from 3 to 8% of the ice volume, which is usu considerably more than the 2.9% that the melt water can dissolve at atm pheric pressure (Scholander, *et al.*). As the iceberg melts, these gas bub are released. The glacier fronts are often some 100 to 300 m deep, and u such hydrostatic pressures the bubbles dissolve as they rise, evidently in ficient amount to cause the supersaturation observed in the upper layer the surrounding water. Supersaturation caused by simple warming of water must be excluded, because the absolute nitrogen concentrations sufficiently high so that the water would be supersaturated even if coole its freezing point.

This mechanism is a natural explanation of the nitrogen supersatura observed in the inner fjord and bay waters of West Greenland. That water may sometimes be found at some distance from its source is dem strated by the data from outer Brede Fjord.

In addition to the nitrogen supersaturation clearly found near the gla fronts, we believe there are indications that some of the other smaller de tures from nitrogen saturation values are real; but our analytical techni and knowledge of exact saturation values do not permit a closer interpreta than that given. Because of the vastly different coefficients of thermal ductivity and of salt and gas diffusion, it is suggested that more accurate kn ledge of nitrogen tension together with a confirmation of the saturation va might provide additional information as to the actual degree of equilibra achieved and contribute to our knowledge of water mass life history and in nal processes.

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The (Ethylenedinitrilo)-tetraacetate Titration of Calcium and Magnesium in Ocean Water

II. *Determination of Magnesium*

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ABSTRACT

Modifications of the EDTA titration of total hardness have been evaluated for determining magnesium in sea water. In this procedure EDTA is the titrant, Eriochr Blue Black B the indicator, and ethanolamine the buffer. Various conditions necessar accurate sea water titrations have been established. A mean magnesium-chlorinity ra 0.06689 was obtained when 30 sea water samples were titrated.

Determination of calcium in ocean waters by (ethylenedinitrilo)tetraac (EDTA) titration has been reported by Pate and Robinson (1958), and d mination of magnesium in ocean waters by EDTA titration is now repo De Sousa (1954) determined magnesium by subtracting the calcium h ness from the total hardness obtained by titrating with EDTA; althoug indicated satisfactory results in sea water analyses, he included no results i paper. Voipio (1957), al Kadhim (1957) and Carpenter (1957) further exp application of the method to sea water samples; al Kadhim determined nesium after separation of calcium byoxalate precipation, and Carpenter a spectrophotometric method for magnesium estimation after ion exch separation of calcium.

Reagents and Indicators

All chemicals, unless otherwise indicated, were of reagent grade.

Calcium Standard Solution. After drying at 105°C, dissolve 1.0009 Mallinckrodt primary standard calcium carbonate in a minimum of 2 N and dilute the solution to one liter.

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lcium and Magnesium Standard Solution. Dissolve calcium carbonate
09 g) in HCl, as above, and dilute to about 600 ml; dry 12.324 g of
esium sulfate heptahydrate over a mixture of hydrates according to Lott
heng (1958), dissolve, add to the calcium solution, and dilute to one liter.
gnesium Standard Solution. Dissolve J. T. Baker Purified Magnesium
ngs (0.2432 g) in hydrochloric acid and dilute the solution to one liter.
thetic Sea Water. Dissolve 1.3 g potassium bisulfate, 12.9 g magnesium
heptahydrate, 1.82 g sodium sulfate, 1.0 g calcium carbonate, 45.7 ml
hydrochloric acid and 21.04 g sodium hydroxide in distilled water and
the solution with standard 1 N sodium hydroxide to a methyl orange
oint. Then dilute the solution to one liter.
monia Buffer. Dissolve 67.5 g of ammonium chloride in 570 ml of
ammonium hydroxide and dilute the solution to one liter.
anolamine Buffer. Dilute 27.5 ml of 12 N hydrochloric acid with 200 ml
illed water, add 155 ml of monoethanolamine (2-amino-ethanol) while
g and dilute to one liter after cooling.
TA (0.0150 M). Dissolve 5.585 g of disodium dihydrogen (ethylen-
rilo)-tetraacetate dihydrate, assaying 100.0%, in water and dilute to
er. This solution was used as a primary standard, to which all secondary
rds were referred. Use either the commercial assayed reagent, or follow
aedel and Knight (1954) preparation.
TA-Mg (0.0149 M). Dissolve 5.585 g of disodium dihydrogen (ethy-
nitrilo)-tetraacetate dihydrate and 0.1 g of magnesium chloride hexa-
e in water and dilute to one liter.
T. Dissolve 1.5 g of Eriochrome Black T in a filtered solution of
of hydroxylamine hydrochloride in 300 ml of 95% ethanol.
B. Dissolve 1.0 g of Eriochrome Blue Black B (K and K Laboratories)
ml of anhydrous methanol.

DURE FOR MAGNESIUM

et 10 ml of the sea water sample into a 125 ml flask, add 25 ml of water,
f ethanolamine buffer and three drops of Erio B solution, then mix.
e the solution with EDTA solution to a true blue end point under in-
cent light. Calculate the milliequivalents per liter of alkaline earth
from the titer of the EDTA.
rate an additional aliquot of the sea water sample to determine the
uivalents per liter of calcium and strontium, using the procedure given
e and Robinson (1958). Subtract this value from the milliequivalents
er of total alkaline earths previously determined. The residual value is
gnesium content of the sample.
titrating sea water samples which have been diluted by appreciable
ies of land water, the presence of interfering ions is probable. Inter-

ference may be eliminated by using one or more masking agents, as rep
in monographs in the field (Schwarzenback, 1957; Welcher, 1958; Bar
1956, 1957).

Investigation of the Method

As commonly performed, an ammonia buffer is used to obtain a pH
and the sample is titrated with EDTA to a blue end point using Erioch
Black T as the indicator. The present work was undertaken to determi
the numerous proposed modifications of this method would enhance it
plicability to the titration of sea water samples. A brief summary of th
vestigation follows.

The results were evaluated statistically by the procedures outlined previ
by Pate and Robinson (1958).

Selection of Buffer. The strong ammonia odor of the usual concent
ammonia buffer has led investigators to examine various alternate b
systems. Patton and Reeder (1956) proposed the use of Thies and Kallir
(1953) ethanolamine-hydrochloric acid buffer; this seemed to offer pro
since it possesses no odor, has good keeping qualities and yields sharp end p

Results of preliminary titrations with this buffer are given in Tables I an
The results found when titrating synthetic sea water were comparable to
obtained with the ammonia buffer. The low results obtained with cal
standards were later found to be due to indicator characteristics. Similarly
anomalous low result found when titrating the magnesium standard (Tab
is explained as being due to precipitation prior to titration (see follo
discussion).

TABLE I. Evaluation of Erio T as an Indicator.

	Titrant	*Buffer*	*Meq F*
Synthetic Sea Water			
Meq Ca and Mg Taken: 1.303	EDTA + Mg	Ammonia	1.3
		Ethanolamine	1.3
	EDTA	Ammonia	1.3
		Ethanolamine	1.3
Magnesium Standard			
Meq Taken: 0.5000	EDTA + Mg	Ammonia	0.4
		Ethanolamine	0.4
	EDTA	Ammonia	0.5
		Ethanolamine	0.4
Calcium Standard			
Meq Taken: 0.5000	EDTA + Mg	Ammonia	0.5
		Ethanolamine	0.4
	EDTA	Ammonia	0.5
		Ethanolamine	0.4

ABLE II. Evaluation of Erio B as an Indicator.

	Titrant	*Buffer*	*Meq Found*
etic Sea Water			
Ca and Mg Taken: 1.303	EDTA + Mg	Ammonia	1.299
		Ethanolamine	1.300
	EDTA	Ammonia	1.300
		Ethanolamine	1.303
esium Standard			
Taken: 0.5000	EDTA + Mg	Ammonia	0.4999
		Ethanolamine	0.4995
	EDTA	Ammonia	0.4998
		Ethanolamine	0.5001
m Standard			
Taken: 0.5000	EDTA + Mg	Ammonia	0.5000
		Ethanolamine	0.4998
	EDTA	Ammonia	0.5000
		Ethanolamine	0.4952

dicator Selector. Erio T (Eriochrome Black T), CI 203 sodium 1-(1-oxy-2-naphthylazo)-6-nitro-2-naphthol-4-sulfonate and Erio B (Erio-ne Blue-black B), CI 201 sodium 1-(1-hydroxy-2-naphthylazo)-2-naph-4-sulfonate were the metal indicators evaluated in this study. Erio T, ugh it is commonly used to determine the end point in total hardness ions, is highly unstable in solution. Suggestions by various authors as to ods of avoiding rapid oxidation of the indicator solution have been sum-zed in several reviews (Barnard, 1956, 1957; Welcher, 1958); these ws have also listed other indicators proposed as substitutes for Erio T. hese, Erio B was selected for evaluation in this study.

able I may be compared with Table II for an evaluation of the use of T and Erio B as indicators. Results obtained were sufficiently accurate arrent further investigation of Erio B.

trant Selection. A poor end point is obtained in the total hardness of cal-. Since the presence of 5% magnesium sharpens the end point, this unt is normally added to the titrant (Diehl, *et al.*, 1950) or the sample. titrant must be standardized after the magnesium addition, and a second ing solution is then required for calcium determinations.

nce all sea water samples contain an appreciable amount of magnesium ell as calcium, no added magnesium is required when an actual sample is titrated. By use of a combined calcium and magnesium standard, pure solution is usable as a titrant in the total hardness determination. es I and II show that there is no loss of precision or accuracy.

Fect of Ionic Strength of the Sample Upon Titration. When ethanolamine r was added to a sample of undiluted sea water, a precipitate slowly formed.

TABLE III. Effect of Varying Ionic Strength of Sample. Titrant: EDT
Mg. Buffer: Ethanolamine.

Sample	*NaCl Molarity Before Titr.*	*NaCl Molarity After Titr.*	*Meq Taken*	*Meq Found*	95 % *CI* ±	% *Dev.*
Erio T as Indicator						
Ca + NaCl	0.487	0.325	0.5000	0.5002	0.0002	0.0
Mg + NaCl.....	0.487	0.325	0.4974	0.5118	0.0035	+ 2.9
	0.428	0.081	1.239	1.241	0.001	+ 0.1
	0.122	0.055	1.239	1.240	0.001	+ 0.1
Sea Water.....	0.462	0.118	1.118	1.111	0.001	- 0.6
Erio B as Indicator						
Ca + NaCl	0.487	0.325	0.5000	0.5001	0.0001	0.0
Mg + NaCl.....	0.487	0.325	0.4970	0.5033	0.0005	+ 1.3
	0.428	0.081	1.240	1.240	0.001	0.0
	0.122	0.055	1.240	1.240	0.001	0.0
Sea Water.....	0.462	0.118	1.118	1.111	0.001	- 0.6

Since this precipitate formed only in the presence of magnesium, it was sumed to be a magnesium-hydroxyl-ethanolamine complex. When indica was added, it was absorbed on the precipitate, coloring it a magenta-pur Upon titrating, the precipitate dissolved, the solution turned its normal and the usual end point behavior was observed. Dilutions of the sample various stages of titration were made as shown in Table III. From the res it is seen that, with either of the indicators used, the sample must be dilu so that the sodium chloride molarity of the titrated sample is 0.1 M or l Results also show that samples with sufficient sodium chloride (0.4–0.5 in Table III) to form a precipitate upon addition of ethanolamine bu may be accurately titrated if they are diluted prior to completion of the titrati

Fivian and Moser (1951) showed that a concentrated sample contain alkali salts gave a false end point with Erio T whereas Schneider and Emmer (1951) found that Erio B was free of this effect. However, results (Table I indicate that the ionic strength of sea water is not great enough to sho difference between these two indicators.

Buffer capacity was checked under verying conditions of dilution. W maximum dilution (10 ml sea water diluted to 50 ml, 87 ml final volu after titration), 1 to 5 ml of buffer yielded a final pH of 9.8 to 10.3.

Conditions Required to Avoid Precipitation. In examining conditions quired for the ethanolamine complex to precipitate, a relationship was fo between the magnitude of the error introduced thereby and the elapsed t after addition of the buffer. Results of a series of titrations, performed to ch this relationship, are shown in Table IV. Accurate results are found u addition of the buffer to the sample immediately prior to titration. Res

ABLE IV. Effect of Time Interval Between Buffer Addition and Titration. Titrant: EDTA. Indicator: ERIO B.

Buffer	*Buffer Added*	*Meq Found*	95 % *CI* ±
Ca+Mg Taken: 1.243			
mmonia.....	Immediately before titration	1.242	
	"	1.241	
	"	1.241	
	Mean	1.241	0.023
anolamine	Immediately before titration	1.241	
	"	1.243	
	Mean	1.241	0.061
anolamine	30 min. before	< 0.3	
Mg Taken: 0.5208			
anolamine	Immediately before titration	0.5218	0.0004
	3 min. before	0.5208	
	5 " "	0.5211	
	8 " "	0.5205	
	10 " "	0.5151	
	25 " "	0.5075	
	30 " "	0.4970	

ABLE V. Effect of Diluting Sample. Titrant: EDTA. Meq Ca+Mg Standard Taken: 1.243.

Buffer	*Buffer Added*	*Meq Found*	95 % *CI* ±
Water Added			
mmonia.....	Immediately before titration	1.238	
"	"	1.241	
	Mean	1.240	0.019
anolamine	Immediately before titration	1.242	
"	"	1.241	
"	"	1.242	
	Mean	1.242	0.001
anolamine	30 min. before titration	less than 1.0 meq	
Water Added			
anolamine	30 min. before titration	1.242	
"	"	1.241	
"	"	1.244	
	Mean	1.242	0.004

are proportionally lower as the time interval between addition of the b and titration increases.

The time relationship of the precipitate formation is modified by dilu of the sample, as shown in Table V. A five-fold dilution of the sample permit a half-hour delay in titrating after the buffer is added. A $2^1/_2$ dilution is insufficient to prevent formation of the precipitate; there immediate titration following addition of the buffer is required.

As a matter of convenience, appropriate amounts of indicator and b were mixed in order that both could be added in a single operation prio titration. If these mixtures were used within several hours, precision accuracy were maintained, although the alkalinity promoted oxidation of indicator. The discolored solution was therefore discarded and a fresh mix was prepared daily.

Magnesium Content of Ocean Waters

Thirty water samples from three ocean stations have been analyzed magnesium using the procedure described. The chlorinities were determ by Mr. Ralph W. Riley, chemist, Oceanography Department, Universit Washington. The method described by Knudsen was followed except

TABLE VI. Magnesium Content of Sea Water.

Cruise: Brown Bear No. 179. Station: No. 26 (49° 12′N, 127° 17′W). Date: November 9,

Depth (*m*)	*Temp.* (°C)	*Chlorinity* (‰)	*Meq Mg/l** (*Calc.*)	*Meq Mg/l* (*Found*)	% *Dev.*	*Mg/*
0	13.28	17.927	120.3	120.2	−0.1	0.06
10	13.28	17.931	120.4	120.2	−0.1	0.06
20	12.96	17.925	120.3	120.2	−0.1	0.06
30	11.74	17.973	120.7	120.7	0.0	0.06
50	7.46	18.069	121.3	121.3	0.0	0.06
75	7.02	18.102	121.5	121.7	+0.1	0.06
100	6.70	18.215	122.3	122.5	+0.2	0.06
125	6.93	18.404	123.6	123.8	+0.1	0.06
143	6.83	18.583	125.0	125.0	0.0	0.06
167	6.85	18.690	125.7	125.6	−0.1	0.06
182	6.84	18.706	125.8	125.9	0.0	0.06
271	5.98	18.780	126.3	126.2	−0.1	0.06
448	4.90	18.873	127.0	126.6	−0.3	0.06
678	4.22	18.941	127.5	127.7	+0.2	0.06
918	3.61	19.007	127.9	128.0	+0.1	0.06
1267	2.99	19.071	128.3	128.4	0.0	0.06
1559	2.44	19.100	128.6	128.4	−0.1	0.06
				Mean		0.06
				Standard Deviation:		±0.00

* Calculated from Mg/Cl ratio of 0.06695 (Thompson and Wright, 1930).

escein was used as the indicator, as recommended by Miyake (1939). authors verified these values by using the regular Knudsen method. esentative results of a single series are presented in Table VI. The mean iesium-chlorinity ratio (by weight) found for the 30 samples analyzed is 689, with an average percent deviation of 0.1%.

hompson and Robinson (1932) summarized the magnesium-chlorinity s reported in 12 previous papers. They concluded that these results were iable because of the analytical techniques used. Thompson and Wright 9), by gravimetric determination of the magnesium as the phosphate, d a ratio of 0.06694 in 30 samples. Their value of 0.06695 (corrected hanges in the atomic weight of phosphorus) has since been accepted as nost valid magnesium-chlorinity ratio of ocean water. Miyake (1939) ted a value of 0.06763 for the ratio of 18 samples by a gravimetric me- and Carpenter (1957) reported a ratio of 0.0667 for 24 samples of apeake Bay water corrected for dilution by an EDTA titration method.

ne magnesium-chlorinity ratio as ascertained from the present work is n 0.1% agreement with the ratio of Thompson and Wright, although is obtained by a radically different analytical method. The speed and icity of the EDTA titration method should encourage its usage in the mination of magnesium in sea water.

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nparison of Norpac Temperature Sections with Average BT Sections along the same Tracks[1]

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University of California, La Jolla

ıe Norpac Atlas (Norpac Comm., 1960), now in press, contains ontal and vertical charts of oceanographic data collected on the Norpac dition, the first multi-nation synoptic survey of the North Pacific Ocean. cal BT temperature sections, included in the Norpac Atlas, were pre- by the author. At that time the synoptic BT temperature observations compared with the average BT temperature observations previously shed by Robinson (1951, 1957) and by Pattullo, *et al.* (1950). These arisons show the relationship of the August 1955 temperature distribu- to average August conditions, based on BT data collected between ears 1941 and 1952. Such comparisons were possible only in the eastern ic, where available BT data had already been analyzed. Now that the PAC Atlas will soon be available to all oceanographers, these comparative erature sections appear to be of general interest.

ıere are two longitude sections and two latitude sections whose locations s follows: 140°W Long., 20° to 59°N Lat. (Fig. 1); 158°W Long., o 56°N Lat. (Fig. 2); 42° to 44°N Lat., 125° to 165°W Long. (Fig. 3); 2°N Lat., 130°W Long. to 165°E Long. (Fig. 4). In these figures the al lines indicate individual BT observations. To simplify comparisons, very fifth isotherm is shown except where gradients are small, in which dditional isotherms have been added. The average isotherms are shown shed lines while those isotherms based on Norpac BTs are solid lines. mparison of the average sections with the quasisynoptic Norpac sections the following similarities:

The isotherms, from their intersections with the surface to their location o feet, have the same general trend in the longitude sections. In the

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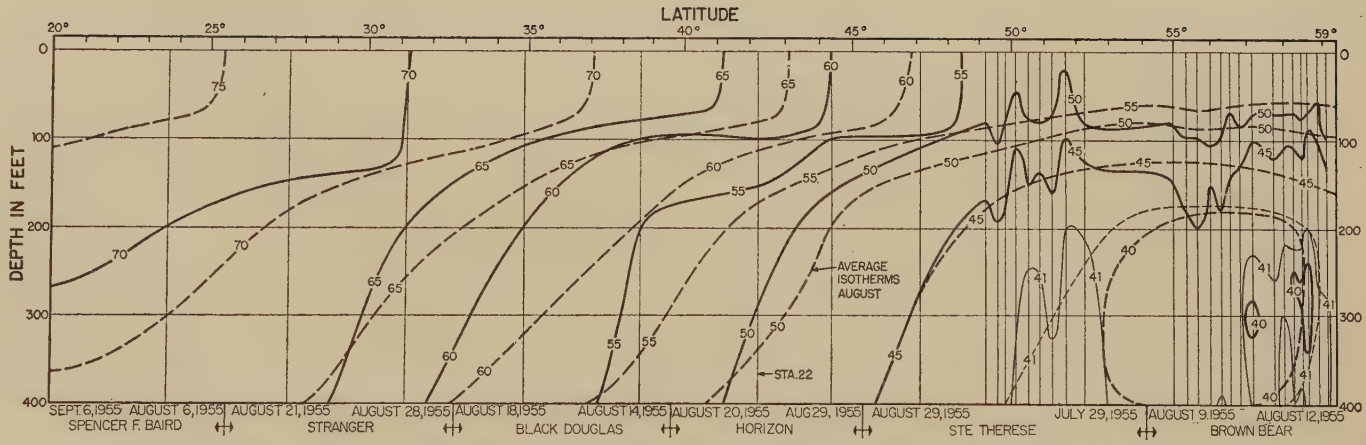

Figure 1. Comparison of vertical temperature sections at approximately 140° W Long. based on Norpac BT observations with average BT temperature section along same track.

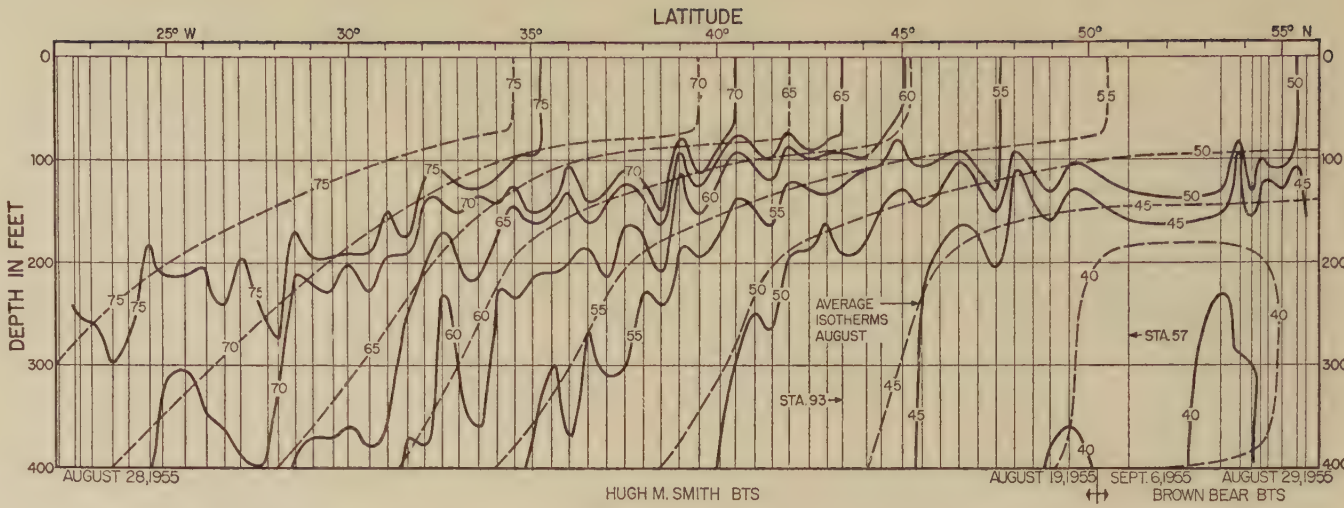

Figure 2. Comparison of vertical temperature section at 158° W Long. based on NORPAC BT observations with average BT temperature section along same track.

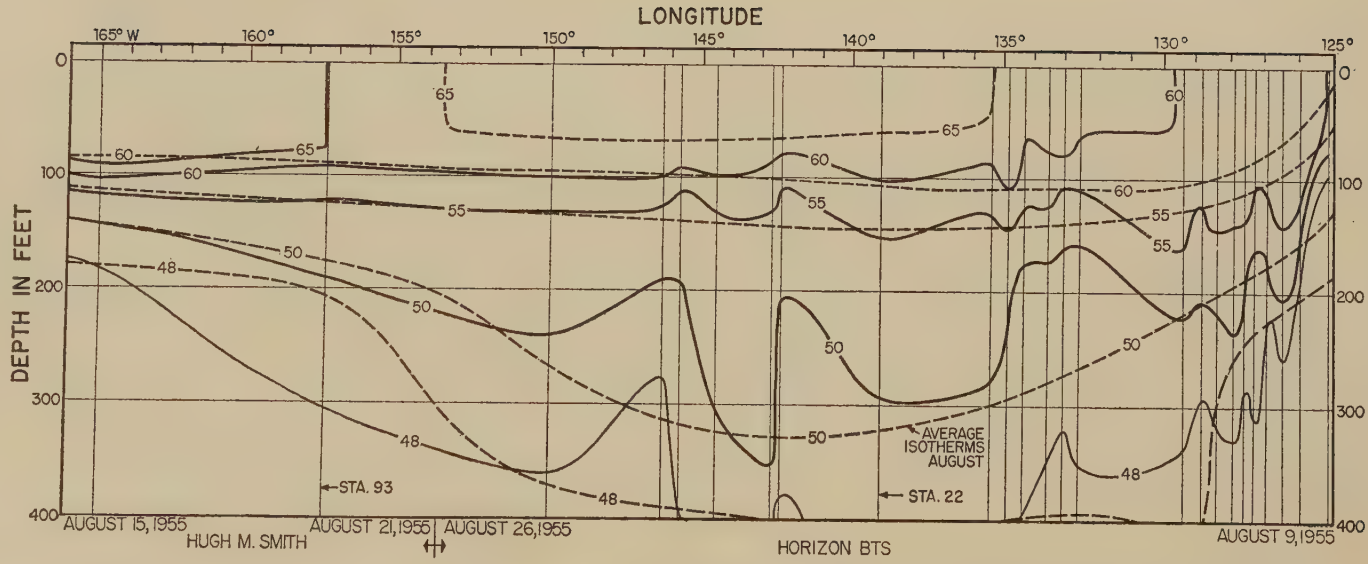

Figure 3. Comparison of vertical temperature section between 42° and 44°N Lat. based on NORPAC BT observations with average BT temperature section along same track.

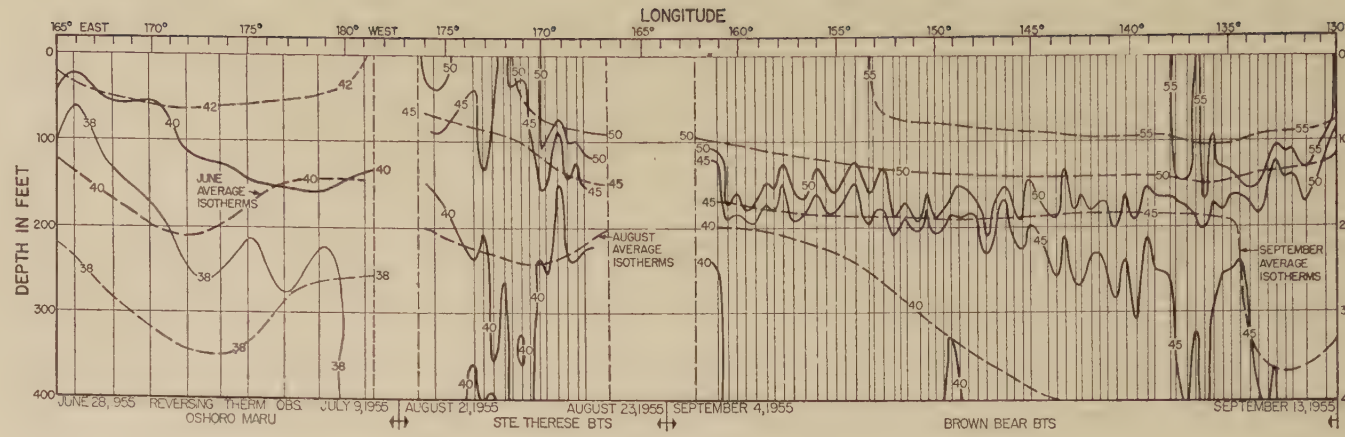

Figure 4. Comparison of vertical temperature section between 51° and 52°N Lat. based on NORPAC BT and reversing thermometer observations with average BT temperature section along same track.

latitude sections there is disagreement above the thermocline but good agr ment at depth.

(2) The average level of the thermocline derived from the NORPAC E agrees with the location of the thermocline in the average sections.

(3) The temperatures at 300 and 400 feet in the NORPAC secti are, in general, within 0.3°F of the temperatures shown by the aver sections.

The differences between the average and quasisynoptic sections are follows:

(1) In the surface mixed layer, the NORPAC 1955 temperatures were lo than the average temperatures with the following exceptions[2]: on the 158 Long. section, south of 45°N Lat. (Fig. 2); on the 42°N Lat. section, v of 155°W (Fig. 3); in these two sections the 1955 temperatures were hig than average.

(2) The depth of any isotherm within the thermocline is extremely varia wherever the 1955 observations are closely spaced. Where observations approximately 20 to 30 nautical miles apart, the displacements of the isothe appear as irregular waves, with amplitudes averaging about 30 feet. The m depth of the thermocline and isotherms, as noted above, agrees well with average. However, in the 140°W Long. section south of 50°N (Fig. where the observations are approximately 200 miles apart, the depth of thermocline (or isotherms within the thermocline) appears as uniform a does in the average section. This is merely a scale effect. The appearanc oscillations in the thermocline in any given section is a function of sp and time between observations. Sections based on widely-spaced observati simply cannot reveal these oscillations, and the deceptive smoothness of isotherms should not be construed as lack of variability. For this rea if depths of isotherms, based on widely-spaced observations, differ by more than 15 feet from the average, the difference should not be conside significant.

If predictions of temperature conditions had been made from the aver charts, then in general they would have given: temperatures above the ther cline within 2°F; temperatures below the thermocline within 0.3°F; thermocline depths within 15 feet.

The major difference between the 1955 observations and the average that the surface layer was colder than average everywhere except in the sou west quarter, where the surface layer was warmer than usual. In the surface mixed layer, the 1955 isotherms were displaced to the south from to 360 miles relative to their average position; however, south of 45°N al

[2] See Hollister (1956) for additional evidence that the entire summer of 1955 was colder than age at Weather Station PAPA and along the British Columbia coast; see also Reid, *et al.* (1958) showed that it was also colder than average in the California Current region in 1955.

W Long. the 1955 isotherms were displaced approximately 100 miles to north. That is, the gradient between the two regimes was steepened. At W Long. (Fig. 2), predicted temperatures and 1955 temperatures would agreed at 45°N.

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Units for Specific Volume of Sea Water

Martin J. Pollak[1]

Considerable confusion has developed in oceanographic literature conc
ing the appropriate units to be used in reporting specific volume and its
cillary parameters, specific-volume anomaly and thermosteric anomaly (sp
fic-volume anomaly at *in situ* temperature and salinity and atmospheric p
sure). The problem revolves around the question, should specific volume
its anomalies be given in terms of liters or cubic centimeters as the uni
volume. The two systems have been used indiscriminately, despite the
that one liter equals 1.000027 dm^3. Of course, any units are acceptable,
vided they are dimensionally correct. Since oceanographic computation
this nature are based on Bjerknes and Sandström's (1910) tables or on ot
derived from them (*i. e.*, Sverdrup, 1933), the problem is narrowed dow
a determination of the units used in these tables. This is precisely the so
of the confusion. The Bjerknes and Sandström tables use the cubic centim
as the unit of volume even though they are based on Knudsen's (1901) ta
of density, without consideration of any change of units.

Actually Knudsen's density values are dimensionless, being defined as
ratio of density at atmospheric pressure to density of distilled water at 4
Since the liter was defined as the volume of one kilogram of distilled w
at its temperature of maximum density, Knudsen's specific gravity and de
in terms of grams and liters are numerically equal. Bjerknes and Sandstr
use of cubic centimeters in place of liters appears justified in view of the
tention of the founders of the c.g.s. system to equate the liter to one c
decimeter. It was not until 1910, the publication date of the Bjerknes
Sandström tables, that results of an elaborate redetermination of the m
volume of the liter were published by the *Comite International de Poi
Mesures*. These results revealed a discrepancy of 27×10^{-6} between the
volume units. Unfortunately this redetermination of the liter and its implica
regarding existing tables for density and specific volume has been ignore
a majority of oceanographers during the last 50 years.

[1] Except for minor emendations by the Editor, this note is published essentially without alte
from a handwritten draft completed just before the author's death on 5 June, 1960. Mr. Polla
a Senior Scientist with the Inter-American Tropical Tuna Commission, La Jolla, California.

nen density (usually in terms of σ_t) and specific-volume anomalies are ed in liter units, their values are numerically correct and there is no er problem. Use of the cubic centimeter, or its multiple, as the unit of ne affects σ_t differently than it does specific-volume anomaly or thermo- anomaly. This difference stems from the definitions of the respective tabulated by Knudsen and by Bjerknes and Sandström. The former ed σ_t as a ratio minus the constant one, multiplied by 10^3. The value of terms of cubic centimeters would be obtained by dividing the complete y value by 1.000027 and then reconverting to σ_t. Because of the limited of densities encountered in the sea, this process is closely approximated btracting 0.027 from σ_t given in grams per liter. Only by redefining σ_t gously to specific volume anomaly could present tables be made to re- nt σ_t correctly in grams per cubic decimeter. Specific volume anomaly, name implies, is the difference in specific volume between the water e under consideration and water of standard temperature and salinity the same pressure. Since transformation of volume units would be y applicable to the sample and the standard, the affect on their difference l be entirely negligible in the last significant place to which the anomaly orted. This implies that specific-volume anomaly is numerically the same ch systems of units. However, the specific volumes of standard water at us depths, as tabulated by Bjerknes and Sandström, must now be cor- l by multiplying by 1.000027.

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TOOLS OF OCEANOGRAPHY

Isotherm Follower[1]

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ABSTRACT

isotherm follower is an instrument that is capable of seeking out a given isotherm ea, locking on to the isotherm, following it up and down, and recording its depth spect to time. This instrument has been employed singly and in triangular arrange- of three to provide the speed and direction of internal waves. It has proven to be e in determining the nature of vertical oscillations of sea temperature.

e principal oceanographic influence on the transmission of sound in the the temperature structure of water. However, one bathythermograph ng at a given time and location may not be representative of the vertical al structure in an ocean area for any length of time. This is because rms fluctuate vertically with reference to both time and distance. It is ore evident that knowledge of the magnitude and geographic distribution nperature fluctuations will help solve problems of sound transmission ons. To acquire such information, an oceanographic instrument called the *m follower* has been developed at the U.S. Navy Electronics Laboratory. is instrument is employed to seek out a given temperature, or isotherm, sea and to record its depth with reference to time. The follower plots l oscillations, or internal waves, as they pass the measurement site.

RIPTION

e complete assembly (Fig. 1) comprises four parts: (1) a sea sensing unit; electric winch (containing a cable to which the sea sensing unit is at-); (3) an electronic unit (containing power-supply, servo-amplifiers, mechanisms, etc.); and (4) two recorders (depth and temperature).

ateful acknowledgments are extended to Mr. D. Baldwin for the electronic design, to Mr. e for its assembly, and to Mr. A. Arnold for the mechanical design. Mr. R. Rayment was re- e for some evaluation tests.

Sea Sensing Unit. This, the submersible section (Fig. 1 A), conta temperature sensor (thermistor bead), which records the temperature particular location and depth on a panel-mounted meter. A second therm bead, similarly located and forming one arm of a bridge circuit, is balanc another arm by a resistance corresponding to the desired isotherm tempera If the bridge becomes unbalanced, a thyratron tube is fired. This activa winch and causes it to raise or lower the sea unit.

This unit is a long, tubular section weighing about 30 pounds. The l end contains the thermistor beads potted in "Scotch Cast" plastic; the end, and the electric cable, are fitted into the streamlined main body, v is about 4 inches in diameter. The main body is sealed from water pre by means of O-rings and packing glands at each end. Inside its housing diaphragm-actuated pressure potentiometer. A second protective externa phragm, separated from the first by an oil-filled area, has its surface ex to the water.

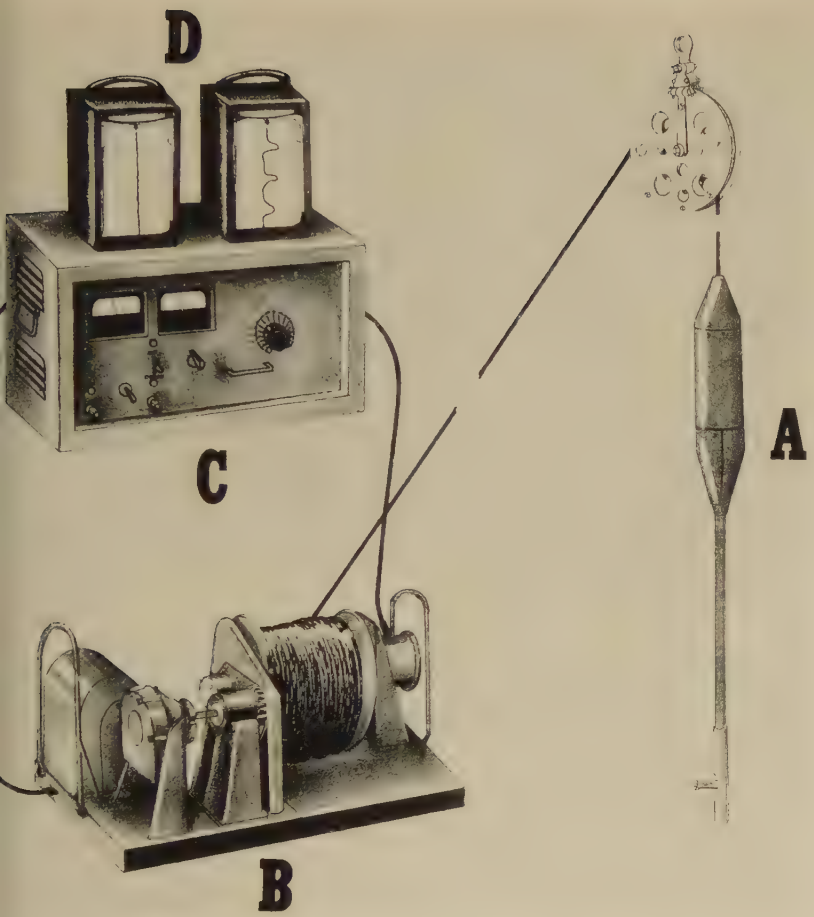
The thermistor beads are set approximately 23 inches below the diaph that actuates the pressure-depth sensing unit. This gives a pressure differ of about 1 lb/in^2, for which correction has been made in the conversi pressure to depth on the read-out of the recorder. The beads are set at stance from the pressure element to avoid measuring the temperature in turbulence caused by vertical movement of the main body; they are mounted on a 2.5-inch elbow-like fitting to prevent sensing the temper in the vertical path of the pressure element and cable.

The cable that leads out of the main body to the winch is Type M (six-conductor), and it is reeled over a sheave fitted with sealed ball bea The sheave is so balanced as to reduce friction on the cable to a mini The cable then feeds into the winch reel.

Winch. The winch and cable (Fig. 1 B) are readily portable and about 130 pounds. The bitter end of the 230 feet of cable is fed into a herm ally sealed slip ring on the end of the winch. In the internal section of the a double packing gland acts as a water seal and a holding device for the Holding is further guaranteed by the automatic switch on the winch, leaves one lay of cable on the drum before the current is reversed. Thi vents the reel from paying out too much cable on the winch, and it kee sea unit from being drawn up to the sheave and damaged.

The entire winch is mounted on a flat, reinforced metal base fitted carrying handles. On shipboard, it is bolted to a platform clamped to th of the ship; on the NEL oceanographic tower it is bolted to the deck gr

The motor has a watertight cover which is splash- and drip-proof. A s electric cable, 25 feet in length, connects a junction box on the motor of the winch to the electronic equipment that feeds power to the mo the winch reel. The 1/4-hp motor, connected with an anti-back-drive gea



ure 1. Isotherm Follower Assembly: *A.* sea sensing unit; *B.* electric winch; *C.* electronic ; *D.* depth and temperature recorders.

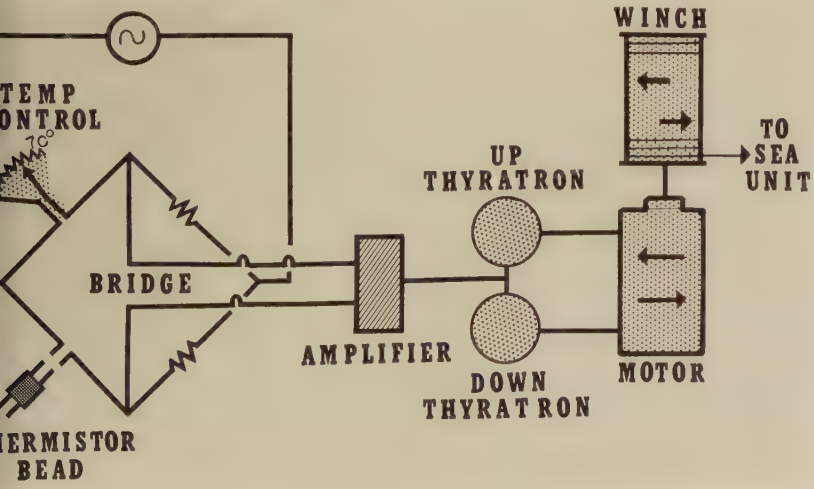


Figure 2. Schematic of electronic circuit of isotherm follower.

Figure 3. Three isotherm followers in operation from booms suspended out from the US oceanographic tower.

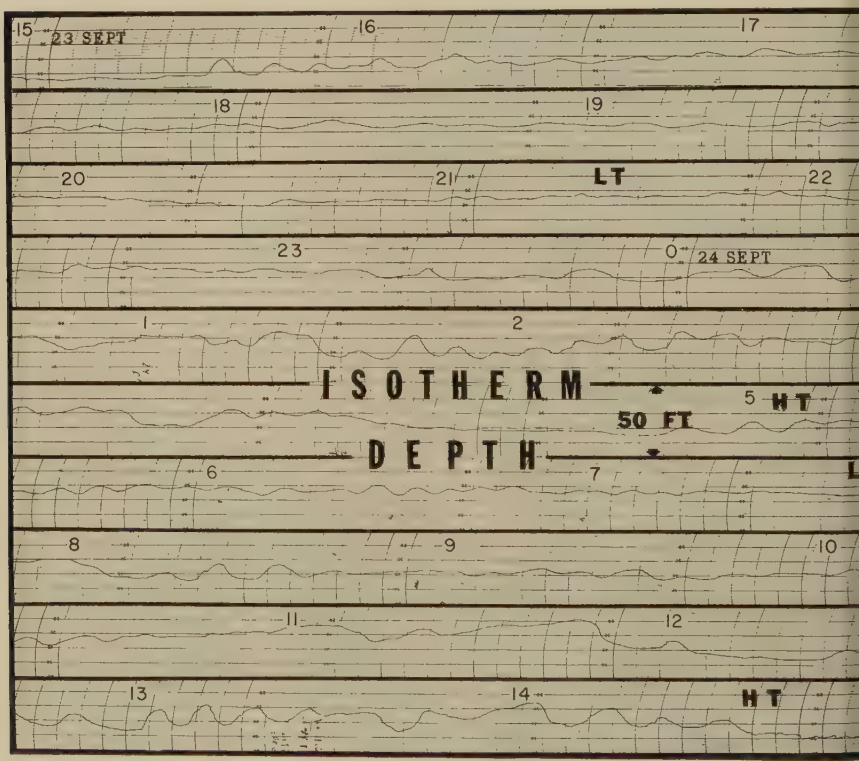


Figure 4. One day's recording from one isotherm follower.

oth forward and backward, depending on the electric signal caused by
es in temperature.
hird cable, also 25 feet in length, leads from the slip-ring assembly to
ectronic unit and feeds through a heavy, watertight coupling connector.
lip rings are of rodium-plated silver alloy and the two wire brush con-
are of gold alloy wire. It is sealed against moisture by a packing
and O-ring seal placed at the junction of the male and female con-
s. This signal cable leads from the slip-ring assembly into the elec-
unit. Thus the electronic equipment can be remote from the winch
bly.

ctronic Unit. A third element is the packaged electronic unit (Fig. 1 C).
ed on the face of its case is a master switch, which activates both the
onic system and the winch; a meter to indicate temperature; another
to show pressure (or depth) of the sea sensing unit; and a dial that en-
an operator to set, by resistance, the temperature desired, in 1°F incre-
between 50 and 70°F.
vo separate circuits are incorporated in the electronic unit: the temperature
tor consists of a thermistor bridge circuit, DC amplifier, and meter-
rcuitry; the temperature-sensing thermistor bridge provides the error
information to the servo-amplifier. Two thyratron tubes form the
ial components of the servo-amplifier and allow current to pass to
inch motor (Fig. 2). The electric current from one tube (up-thyratron)
the winch to run forward; the current from the other (down-
ron) causes the winch to run backward. The winch will wind in or
t the sensing unit, depending on the signal it receives from the ther-
bead.
e pressure element, also a part of another bridge circuit, is connected to
libated depth meter on the case. This, like the temperature part, has
-off to a recorder.

orders. One Esterline-Angus unit records the temperature (from 50–70°F)
bead in the sensing unit, and another gives the depth. The latter can
erated at a full scale of 0–100 feet or, by interchanging the pressure
ucer, to a full scale of 200 feet. Paper speed is adjustable, though it is
lly set at one foot per hour.

TION

ts. The thermal response characteristics of the isotherm follower were
nined in the laboratory by means of a tube (8 feet long and 9 inches in
ter) containing a window 4 feet long. The tube was filled with almost
volumes of water and kerosene. The desirable thermal properties of the

two liquids, as well as their immiscibility, rendered a sharp temperature dient between the two phases.

The sea sensing unit was lowered into the tube to the boundary regio the two liquids. At this juncture, thermal response tests were begun by se the temperature selector at successive temperatures intermediate between at the bottom of the kerosene layer and that at the top of the water l This condition caused the unit to respond in an oscillatory or hunting ma It was found that, for a temperature gradient of 0.27°F/inch, the mean v ity was 3.7 in./sec. When the temperature gradient was reduced to 0.17°F/ the mean velocity of the follower was 1.5 in./sec. The frequency of the lations was found to be 66 cycles/min. The temperature differences a interface caused the follower to overshoot the temperature it was seekin the following amounts: at 1°F, 4.5″; at 2.5°F, 7.5″; at 3.2°F, 8.7″. latter gradients are stronger than those observed in the sea.

The most complete tests were made during several sea operations. the temperature recorder provides a monitor of sensing unit tempera it is run concurrently with the depth or pressure recorder. It was establ that under the most adverse conditions the temperature remained w ±0.5°F of the temperature set on the control dial. This clearly demonst that the sensing unit was following the vertical oscillations of an isot in the sea.

Operation. To determine the vertical variation in any selected isother the sea, the isotherm follower may be operated in one of several ways. It be suspended from an anchored or drifting ship, with the sensing unit s a given temperature, normally chosen from the sharpest part of the the cline. Another *modus operandi* is from a moving vessel, wherein the foll may be towed at slow speeds to obtain the geographic distribution of th sired isotherm. At other times, two or more followers may be set at diff temperatures in the same location to obtain vertical gradients.

For some studies it is desirable to record the temperature at the same in three locations. This can be accomplished conveniently by using m control, adjusting the sensing unit to the desired depth, and allowing temperature to record with reference to time. Such an arrangement has operated continuously for seven days.

Another method, probably the most informative, deploys three sensing in a triangular arrangement. When the time is synchronized, the dire from which the internal waves are coming is easily computed from the ferences in time of arrival of the same wave at the three locations. One operation was carried on from three fixed points of a triangle: (1) the oceanographic tower, (2) an anchored ship, and (3) a small anchored each being located about 250 feet apart. The most convenient place however, was a triangular distribution of three followers suspended

ot booms mounted on the NEL oceanographic tower (Fig. 3), with the recorders located in the instrument house. Time markers in minute als were made simultaneously on the margin of the three tapes by means iming device. Under this arrangement, three units were operated con- ly for periods of up to seven days. One day's record from one isotherm ver is reproduced in Fig. 4.

LTS

ie nature of the observed internal waves, at the usual measurement site the continental shelf near San Diego, Calif., varied from wave to wave. frequently came in groups, separated by periods when the thermocline elatively stable. However, at the measurement site, significant internal s (*i. e.*, >2 feet in height and >2 minutes in period) were present 76% e time, and the median of the significant waves had a height of 5.1 feet period of 7.2 minutes. Waves of this type are easily followed and graphic- ecorded with the isotherm follower.

ocessing of such waves was accomplished by scaling off the depth of the rm for every minute and punching the values on IBM cards. Since the ning can be accomplished faster than the recording, backlogs of this phase e processing were negligible. An analysis by computing machines will d on the use to be made of the data. At the present time, depth-time ents, wave periods, wave amplitudes, autocorrelations, and power spec- with reference to time are being studied.

nus the isotherm follower, which furnishes a record of isotherm depth reference to time, has proven to be a useful oceanographic instrument for tudy of internal waves.

A Multiple-Detector Irradiance Meter and Electronic Depth-Sensing Unit for Use in Biological Oceanography[1]

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ABSTRACT

The underwater irradiance meter or submarine photometer described here is desig to operate in the upper 100 to 150 m. It permits direct measurement of the downw blue-green irradiance (480 mμ) to a depth of 100–120 m on a clear day in water wit attenuation coefficient in the blue-green region of the spectrum of approximately 0.0 The meter can accommodate as many as five individual detector units as well as an assoc depth-sensing element. The detectors are cosine flux collectors, equipped with a dry self-generating, barrier layer cell. Any single detector unit may be readily oriented down, or horizontally. Selection among the detectors is made by energizing the switc mechanism with a push button. Their output is measured in the vessel's laboratory w damped multirange microammeter of low internal resistance. The associated depth-sen unit is transistorized and battery-powered and is capable of measuring depth down to 2 with an accuracy of ± 2% in the 50–200 m range. The unit is stable, rugged, and relat insensitive to temperature changes in the range between 2° and 25° C. The detector depth signals are carried by a two-conductor electrical cable, which also supports th strument. A sea return is utilized in the detector unit switching assembly.

Introduction. The need for a versatile irradiance meter for use in connec with studies of phytoplankton ecology has been plain for some time. Ma biologists and biological oceanographers studying phytoplankton and lit alga photosynthesis are now frequently measuring attenuation coefficients light levels; they require more complex and precise information as their st become more elaborate.

[1] Contribution from the Scripps Institution of Oceanography, New Series. This paper repr results of research carried out by the University of California under contract with the U.S. D of Commercial Fisheries.

[2] The authors wish to acknowledge the information received from John Tyler, research ph of the Visibility Laboratory of the University of California, Scripps Institution of Oceanograph Jolla, concerning the design and characteristics of the flat plate collectors used in the detecto

ıe meter described here is the result of the authors' experience over seven in measuring attenuation coefficients and developing instrumentation. particular instrument has been in intermittent use and under modification wo years. The present design has proved to be reliable and of general :ability for high seas research in which the objective is to study, in the the role of light in photosynthesis.

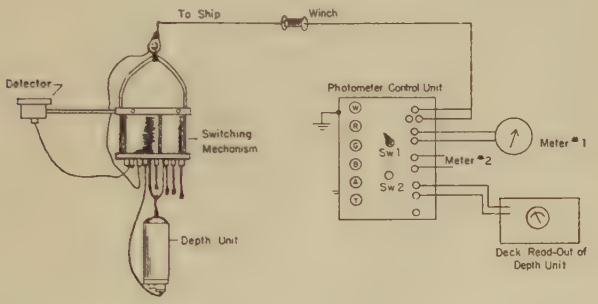


Figure 1. The irradiance meter and depth-sensing unit.

he meter (Fig. 1) is a single or multidetector unit capable of measuring rradiance on a flat surface oriented at any desired angle. The individual collectors may be oriented in advance to measure the attenuation coef- ıt for downwelling or upwelling irradiance. By combining these two urements it is possible to compute the reflectance at an imaginary hori- ıl plane in the sea, or to obtain the ratio of the irradiance on a plane facing un to that on a plane facing away from it. By proper selection of optical s, the instrument can be set up to measure either the same optical property number of band widths nearly simultaneously or several optical properties he same band width.

radiance is easily measured and by its use the results from different areas regions can be standardized and compared. Furthermore, attenuation icients k calculated from the irradiance data using the following equation

$$k_\lambda = \frac{2.30}{L}(\log I_{\lambda,h} - \log I_{\lambda,h+L})$$

ıseful in biological and physical oceanographic studies (Holmes, 1957 or drup, *et al.*, 1942).

he Detector Unit. Each detector unit (Fig. 2) consists of a photocell hous- i) and a threaded cap (c). The latter accommodates the Lambert or cosine ctor (a), elevated about 1 mm above the cap and the lucite window (b). atertight seal between these components is effected by rotating the threaded

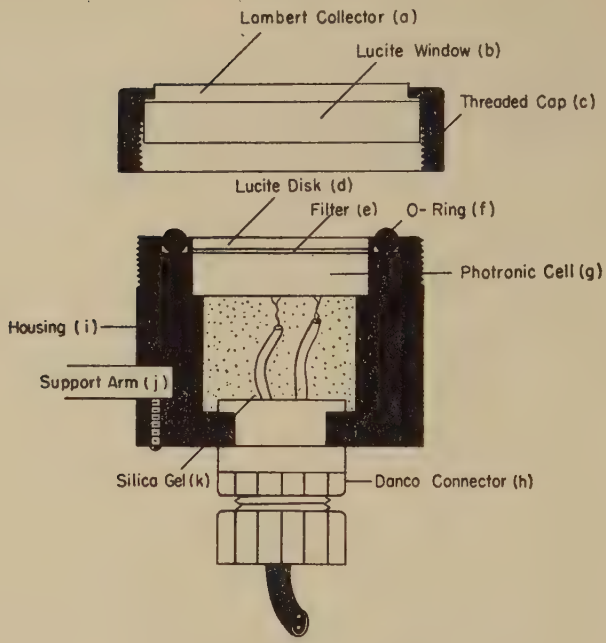


Figure 2. The detector unit.

cap until a seal is obtained between the O-ring (f) and the lucite win The color and/or neutral filter (e) may be placed above the photocell when gelatin filters are employed, they are held in contact with the phot by a lucite disk (d). Silica gel (k) placed in the space below the photocell pre window fogging and moisture damage to the gelatin filter. The electrical from the photocell are taken through the housing in a nylon stuffing tub (Danco, Size 1, Danielson Mfg. Co., Danielson, Conn., packing asse for the tube, Dorn Equip, Corp., Boston, Mass.); they terminate in a plug (No. X8104–63, Joy Mfg. Co., Compton, Calif.).

The particular cosine collector used in this instrument is fabricated milk-white translucent plastic (Rohm and Haas, Plexiglass 2333, Phil phia, Pa.), the surface of which has been carefully abraded with carborun (Grit No. 180) to give it cosine-collecting properties when submerged. T are of course other ways to build cosine collectors; the important thin know is the properties of the flux collector.

Hermetically sealed barrier layer (dry disk) self-generating cells (M 856RR), manufactured under the name Photronic Photoelectric Cell (W Electrical Instrument Corp., Newark, N.J.), have been employed in detectors. These cells have proved stable and rugged enough for use in type of work.

Figure 3. The underwater switching unit.

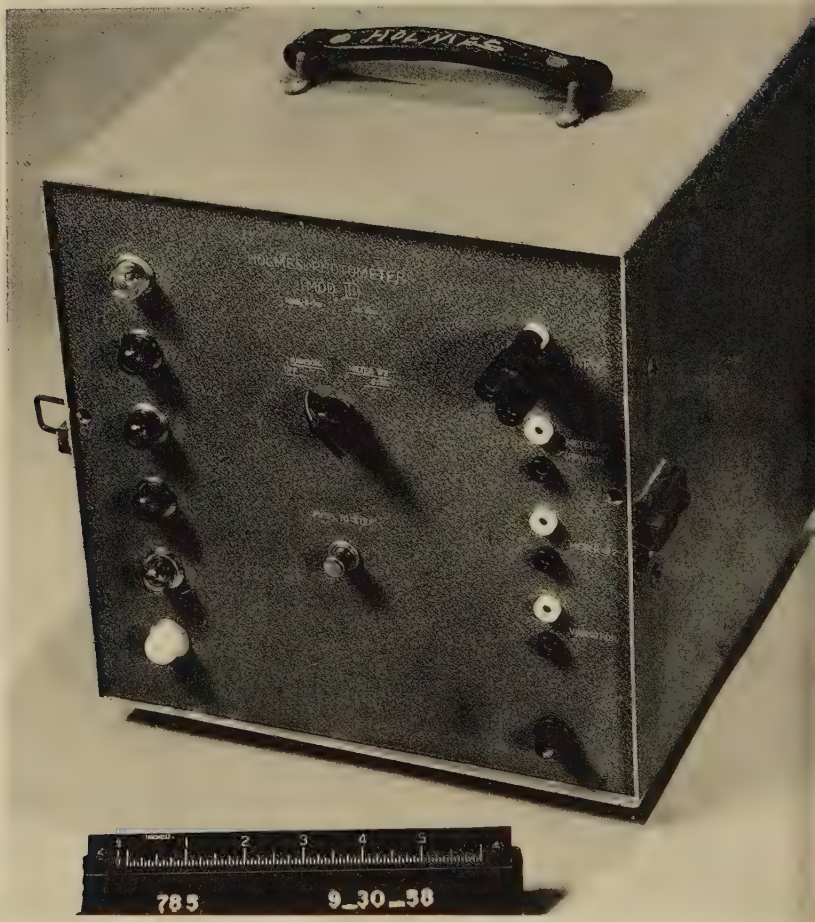


Figure 4. The deck control unit.

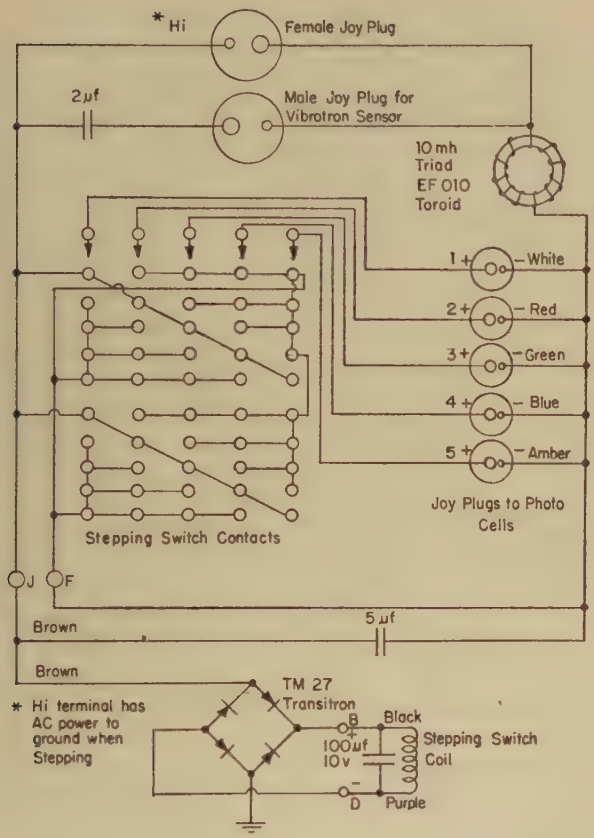


Figure 5. The underwater switching unit. Schematic diagram.

itching Mechanism and Deck Control Unit. The detector units are mounted ainless steel rods, approximately 40 cm long, which are inserted into holes ded on the top plate of the underwater switching unit (Figs. 1, 3). The tation of the detectors may be adjusted and maintained by utilizing the set-screws mounted in either the detector or the switching mechanism. rical continuity from the detectors is achieved by means of connecting oy connectors (Fig. 3).

he underwater component of the switching mechanism consists of an ed brass housing which contains a rotary stepping switch (Type 44, matic Electric Sales Corp., North Lake) and associated equipment 3, 5). Seven outlets pass through the bottom of the housing; five for use detectors, one to connect with the depth element, and one to connect e cable that supports the instrument and carries the signal to the photo-

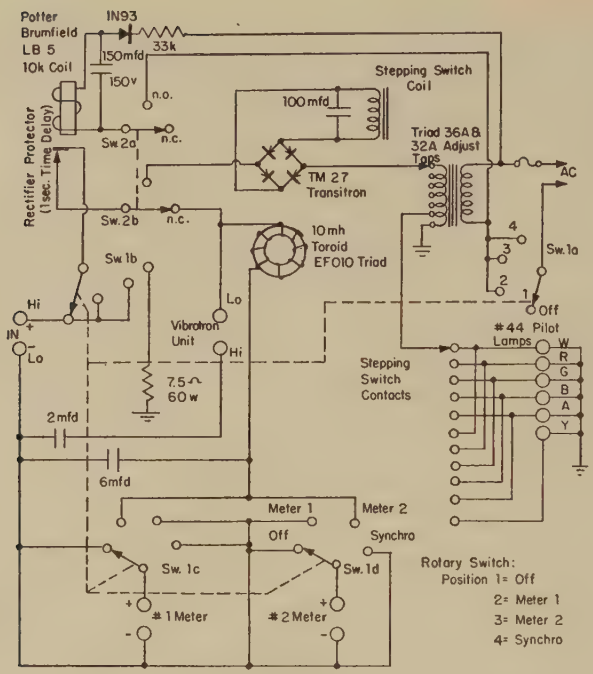


Figure 6. The deck control unit. Schematic diagram.

meter winch, whence the signal goes to the deck control unit. The selec of the particular detector is controlled by means of a push button on the control unit ("Push to Step", Sw. 2, Figs. 4, 6).

The deck control unit (Figs. 4, 6) is energized from 115-volt, 60-cy AC power. When the instrument is turned on, one of six panel lamps sixth has no detector associated with it) indicates which of the five dete are connected to the meter or recorder jack located on the right-hand sid the instrument. Provision has been made for the use of two meters or of meter and/or a meter-amplifier combination by the inclusion of a se outlet on the control unit. The selection of these outlets is controlled switch mounted in the middle of the control unit panel above the energi (Push to Step) button.

There are several fundamental limitations to the mechanism as it present designed. First, a maximum of 4 ohms is all that can be tolerated conductor between the deck and underwater units. If the resistance is incre above this limit, the photocell output becomes less linear at high light l and effectively less sensitive. Further, since a sea return is used and is incl in the 4-ohm limitation, the instrument is not designed to be used in

. Because the sea return is normally less than 1/4 ohm, it is clear that lectrical conductor is essentially the limiting factor.

ıe circuitry is straightforward, as schematized Figs. 5 and 6 show. Two l features merit mention. The photocells not in use are shorted (as re-ıended by the manufacturer); and a specific control position is provided e deck control unit to permit easy and rapid synchronization between the ınits if they require rephasing. In addition, a simple filter system is used event any interaction between the depth unit signal, which is AC, and)C potentials from the photoelectric cells.

rformance of the Meter and Measurement of Attenuation Coefficients. The nt generated by a Photronic cell in a constant light field is a function ll sensitivity, external resistance, and temperature. During routine ir-ıce measurements, the first two of these factors are constant; only the erature of the cell varies. Technical information supplied by the manu-rer shows that with an external resistance of about 105 ohms, the output cell in a constant light field of 200 foot-candles will vary from −2% to , in the temperature range 0–40°C, using 20°C as the reference point. deviation is less in the temperature range 10–25° ($c \pm 1.5\%$); the data ot corrected to allow for this error.

ABLE I. Linearity of Response of Two Photronic Cells as Determined from Optical Bench Measurements.

	μA Output at 105 ± 1 Ohms					
lux	Cell No. 8			Cell No. 3		
retical)	4 Feb.	10 Mar.	21 Oct.	29 Dec.	3 Feb.	21 Oct.	26 Dec
1000	1000	1000	1000	1000	1000	1000
814	818	820	819	812	820	812
656	658	660	660	653	660	657
528	532	535	535	527	535	542
426	425	430	430	421	424	–
342	342	342	342	337	342	348
272	273	275	274	269	274	280
217	218	218	220	213	222	226
174	175	175	174	171	174	182
138	139	138	140	136	139	144
111	112	105	112	109	112	115
88.4	87.5	85	88	85.8	87.9	92
70.4	69.5	69.5	70.1	68.6	70.1	72.1
44.5	44.2	43	44.6	43	44.2	46.5
28.3	–	30	–	27.6	28.6	–
18.1	–	–	–	17.6	18.1	–
11.5	–	–	–	11.2	11.6	–
7.3	–	–	–	7.2	7.4	–
4.6	–	–	–	4.45	4.9	–

The type 856RR Photronic cells are stable in terms of linearity of respo
However, since no two cells are identical, it is important if reliable meas
ments are to be made at high light levels to determine the linearity of resp
for each cell under the resistance load that will obtain during actual meas
ments. This may be done on an optical bench or with a series of neutral fi
of known transmittance. In Table I, linearity-of-response data obtaine
intervals over an 11-month period are given for two type 856RR cells. T
is an indication of a slight increase in linearity over the time interval, but
may not be significant.

The flux sensitivity of one of these cells has remained virtually cons
($c \pm 5\%$) for two years.

During routine measurements at sea, the output of the detector un
has been measured with a Rawson multimeter (Model 501, special slow
sponse) possessing five scales (0–50, 100, 200, 500, and 1000 μA), each
an internal resistance of 100 ohms. The meter has been inductively dam
so that its response time is on the order of 45 sec. It has been assumed t
under conditions of rapidly fluctuating light levels such as are frequently
countered in the upper 15 m, the damped meter gives an estimate of
average light levels.

Attenuation coefficients may be readily determined providing visible i
dent irradiance is measured simultaneously with the output of the detect
at a series of depths and providing the linearity of the detector element is kno

Under ideal field conditions this irradiance meter gives very reproduc

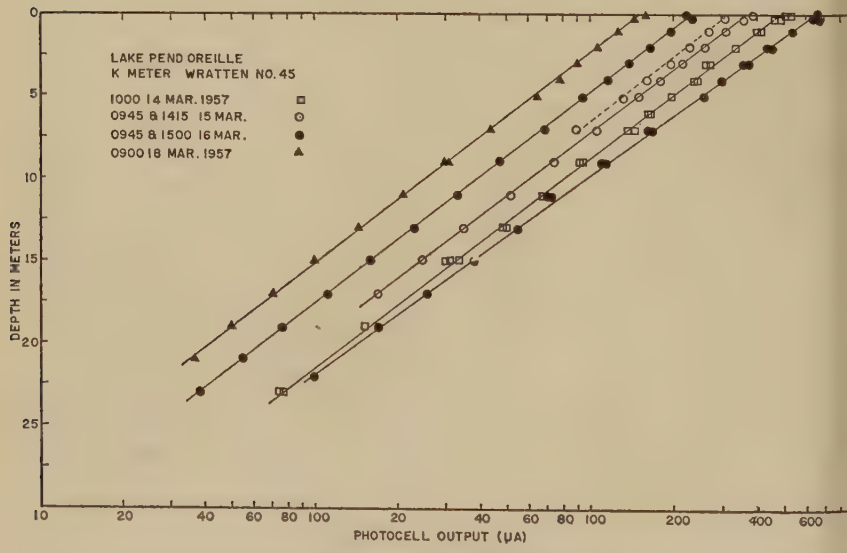
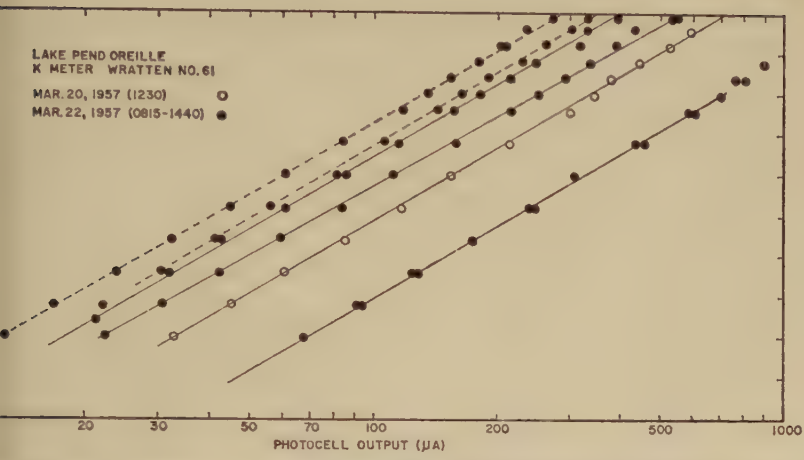


Figure 7. Relative irradiance at different depths. Lake Pend Oreille. Wratten No. 45 filte



ıre 8. Relative irradiance at different depths. Lake Pend Oreille. Wratten No. 61 filter.

s, as the data presented in Figs. 7 and 8 demonstrate. These data were ted in Lake Pend Oreille, Idaho, in March 1957, with a different ning mechanism but with the same detector and galvanometer mentioned . Correction for departure in linearity and for changes in incident solar ion has been made. The corrections for incident radiation were made in a way that the various curves are not superimposed. Thus the relatively departures in slope (the attenuation coefficient) between the eye-fitted s may be readily seen. The Wratten No. 45 filter has its transmission at 480 mμ and the No. 61 at 520 mμ.

mparable replicate measurement series obtained in the sea show that values are more variable than those obtained in Lake Pend Oreille. ertical oscillations of the vessel and the high wire angles resulting from rift or subsurface currents make measurement more difficult and less n. A typical series of measurements obtained on four separate lowerings irradiance meter in the Pacific Ocean about 20 miles west of La Jolla, rnia, on 1 May 1959 is illustrated in Fig. 9. Conditions were quite ble during this set of observations: the sky was nearly uniformly over- ea and swell were moderate, and wire angles were less than 5 degrees. ctions similar to those applied to the data in Figs. 7 and 8 were also The rather obvious differences in the slopes of these curves in the layers probably are the result in part of inaccurate depth determinations. he depth element described in the next portion of this paper been em- , these curves might have become essentially parallel, as were the Pend e profiles (Figs. 7, 8), where depth determinations had essentially no error. ile the sensitivity of the Photronic cell is not particularly high, measure- in the blue-green region (Wratten No. 45 filter) may be made to depths

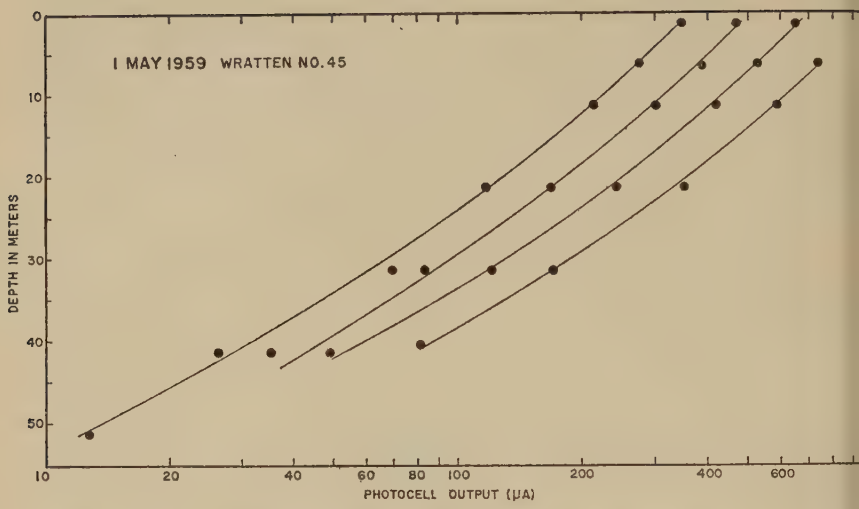


Figure 9. Relative irradiance at different depths. Pacific Ocean 20 miles west of La Jolla, Calif Wratten No. 45 filter.

of approximately 100 to 120 m on clear days when the water possesses attenuation coefficient (in this same spectral region) of approximately per meter. Under these conditions about 1.8% of the blue-green light etrating the sea surface will be found at 100 m depth. A considerable incr in sensitivity of the unit may be easily obtained by amplifying the photo signal.

The Depth-sensing Unit. In order to measure attenuation coefficients precision, instrument depth as well as light levels must be measured accura Experience gained from examining many irradiance-depth profiles has i cated that depths computed from wire length and wire angle measurem cease to be reliable with wire lengths exceeding 50–60 m if high wire an (*i. e.*, 40–45°) are encountered. Thus if reliable light measurements de than approximately 60 m are desired, the photometer depth should be meas by some other technique. This requirement led to the development of depth-sensing unit described below.

For convenience in describing it, the component parts of the depth are schematized in Fig. 10. The pressure-sensing element (Vibrotron Di Pressure Gauge, Model 101-12-300, Borg-Warner Controlls Corp., S Ana, Calif.) consists of a vibrating wire maintained in a vacuum and dr by a transistorized, battery-powered amplifier. Pressure changes on the of the wire that is attached to a pressure diaphragm alter the tension of wire and hence its frequency.

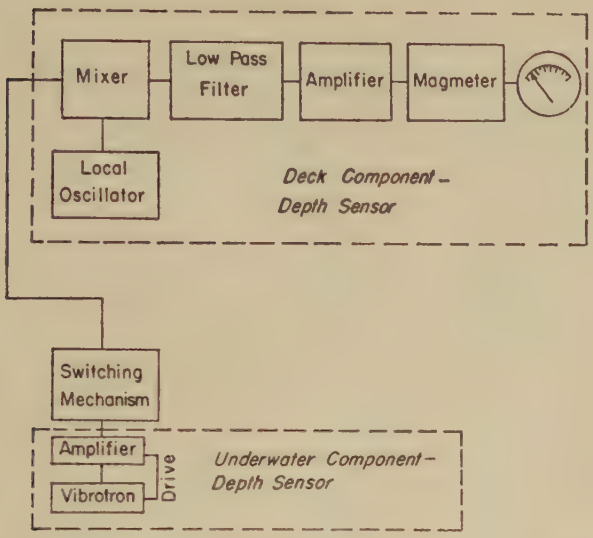


Figure 10. Principal components of the depth-sensing unit. Diagrammatic.

ıe deck component of the depth-sensing unit is connected to the meter ol panel (Fig. 1). The amplified signal from the vibrating wire, coupled he irradiance meter's switching mechanism, feeds into a mixer, where cal oscillator produces a frequency which corresponds to the Vibrotron sia frequency. The resultant difference frequency is fed through a low-lter to remove unwanted components and then amplified. The amplified passes through a Magmeter (No. F-5161, Airpax Products Co., Balti-

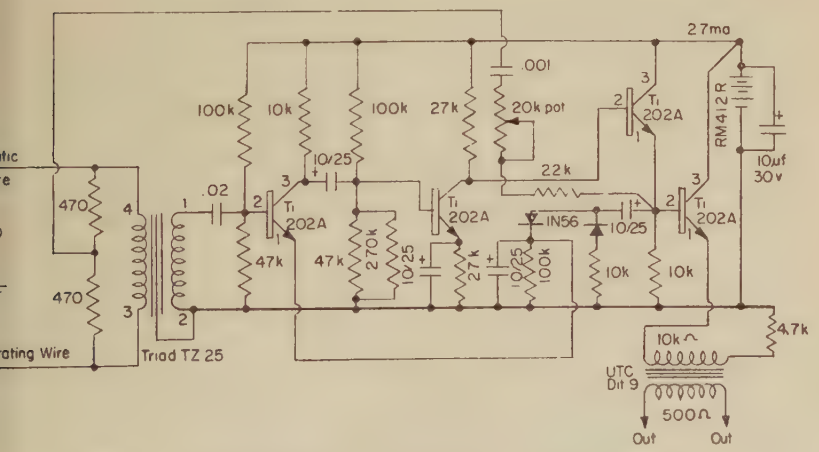


Figure 11. Depth-sensing unit. Wiring diagram of underwater unit.

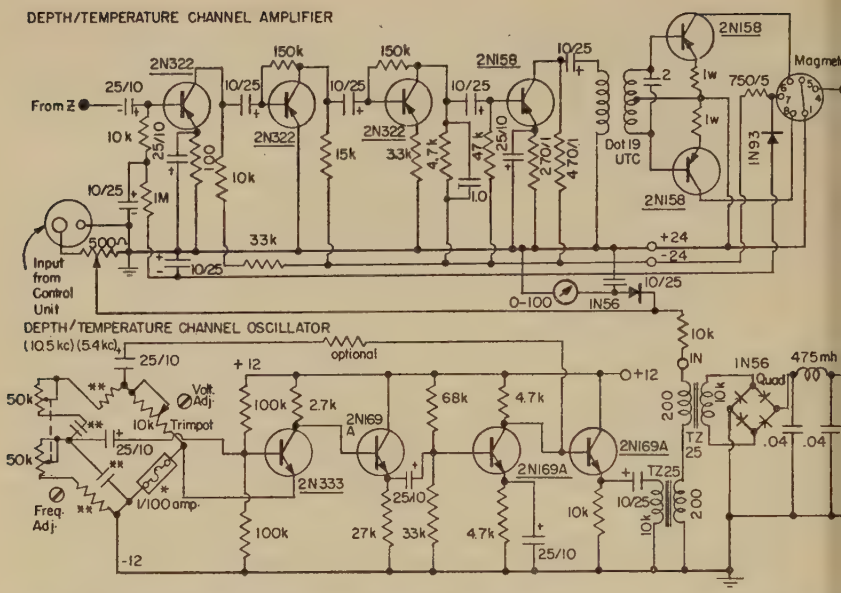


Figure 12. Depth-sensing unit. Wiring diagram of deck unit. * 8 AG Little fuse. ** Values d on frequency. 904: Texas Instrument or 2N333 G.E. 2N169A; 2N322: G.E. 2 C.B.S.

more, Md.) and is then read on a 0–100 μA meter. Figs. 11 and 12 show wiring diagrams of this circuitry.

Battery life in the deck component is of the order of several hundred h The depth component is somewhat underpowered, but battery life norm averages in excess of 10–11 hours with continuous operation at room t perature (18–24°C).

Calibration and Reproducibility of the Depth Unit. The depth unit calibrated against an Aschcroft 0–600 psi dead weight gauge (type 1300) tween 0 and 300 psia. During the test the Vibrotron frequency was monitored with a Berkeley Eput Meter, Model 554-M. These data presented in Table II and in part in Fig. 13.

A test of the reproducibility of the depth unit was made at room temp ture (25°C) by taking 11 measurements at 5 pressures (50, 100, 150, 200, 300 psia) after zeroing the instrument at atmospheric pressure. Each se measurements between 0 and 300 psia was made by progressively increa the pressure in the increments given above. After each series the pressure released and the instrument was allowed to equilibrate at atmospheric pres for a minute or two before beginning the next series. The Vibrotron frequ was also monitored directly with the Berkeley Eput Meter. The data obta

BLE II. CALIBRATION OF THE PHOTOMETER DEPTH UNIT (25°C).

	A		B	C
	Deck Unit Reading	Vibrotron Frequency	Vibrotron Frequency	Vibrotron Frequency
.....	0.0	11108	–	11108
.....	4.0	11067	11066	11066
.....	5.0	11046	11045	11044
.....	8.5	11004	11003	11002
.....	11.5	10962	10961	10960
.....	14.5	10919	10918	10918
.....	17.5	10877	10876	10876
.....	20.5	10834	10833	–
.....	23.5	10791	–	–
.....	27.0 –	10748	10747	10789(?)
.....	30.0	10705	–	–
.....	33.5	10661	10660	10659
.....	36.5	10618	–	–
.....	39.5	10574	10573	–
.....	43.0 –	10530	–	–
.....	46.5	10486	10484	–
.....	50.5	10441	10440	10439
.....	59.5	10306	10305	–
.....	66.0+	10215	10214	10213
.....	80.0	10031	10030	–
.....	83.5	9984	–	9983
.....	87.0 –	9937	–	–
.....	93.5	9842	9842	–
.....	100.5	9746	9746	9745

; manner are given in Table III along with the mean value, standard ion, and coefficient of variation for each pressure series.

lance at the Vibrotron frequency at each pressure, as read on the Berkeley , shows the high degree of consistency in the results. The deck compo- f the depth unit cannot be read as accurately as the frequency meter, it as stable, but it is entirely adequate for the purpose for which it was ed. The coefficient of variation is not constant over the pressure range erages somewhat less than 1%. Thus, for 95% confidence (±2 stan- leviations) at room temperature, the depth estimate would be accurate ut ±2%.

e underwater component of the depth unit was found during its design sembly to be relatively insensitive to temperature changes between 0 °C; and this matter was investigated further in the laboratory with the a whole. In this test the pressure was measured with a 0–300 psi Heise n gauge (No. H-1731) which was found subsequently to need reca- on, but relatively the readings are assumed to be satisfactory. The depth as allowed to equilibrate at room temperature (25°C) when readings

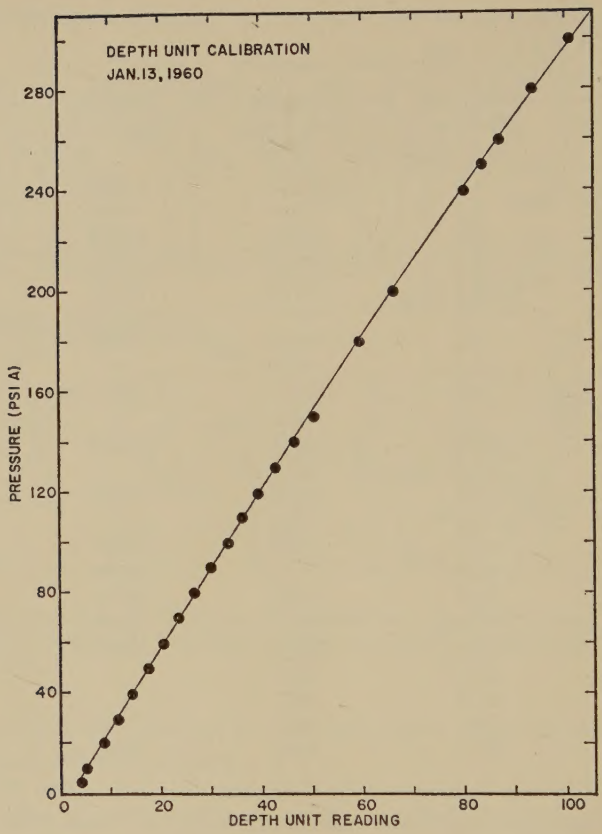


Figure 13. Depth unit calibration.

were taken, after which it was immersed in a water bath at 2–3°C for t hours before a second set of readings was taken. This procedure was rep three times; the data are given in Table IV. The slight temperature observed should be taken into account if depth measurements are being in arctic waters.

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TABLE III. Reproducibility of the Depth Unit (25°C).

Atmospheric Pressure		50 psia		100 psia		150 psia		200 psia		300 psia	
Vibrotron Frequency	Unit Reading	Vibrotron Frequency	Unit Reading	Vibrotron Frequency	Unit Reading	Vibrotron Frequency	Unit Reading	Vibrotron Frequency	Unit Reading	Vibrotron Frequency	Unit Reading
11107	0.0	10876	16.5	10660	32.5	10440	50.0	10214	66.0	09746	101.0
11107	0.0	10876	16.5	10661	32.0	10440	50.0	10217	66.0	09746	100.5
11107	0.0	10877	16.5	10661	32.0	10441	50.0	10214	66.5	09746	100.5
11108	0.0	10876	16.0	10661	33.0	10440	50.0	10214	66.5	09746	101.0
11106	0.0	10876	16.0	10661	32.0	10440	49.0	10214	65.0	09746	99.5
11107	0.0	10876	16.5	10660	32.0	10440	49.5	10215	65.5	09746	100.0
11107	0.0	10877	16.5	10661	32.5	10441	50.0	10215	66.0	09746	100.0
11108	0.0	10876	16.5	10661	32.0	10440	49.5	10215	66.5	09746	100.0
11106	0.0	10876	16.5	10662	32.0	10441	49.0	10214	65.0	09746	100.0
11107	0.0	10876	16.5	10661	32.0	10441	49.5	10214	65.5	09746	100.0
11107	0.0	10877	17.0	10662	32.5	10441	50.0	10215	66.0	09746	100.0
11107	0.0	10877	16.5	10662	32.0	10440	49.5	10215	65.0	09746	100.0
11107	0.0	10876	16.4	10661	32.2	10440	49.7	10215	65.8	09746	100.2
0.6030	–	0.5222	0.257	0.454	0.335	0.522	0.390	0.904	0.582	–	0.451
0.0054	–	0.0048	1.57	0.0063	1.04	0.00500	0.784	0.00885	0.885	–	0.450

Mean value

Standard deviation

Coefficient of variation (percent)

TABLE IV. Temperature Effect on the Depth Element at Various Pressures*.

	18 January 1960			19 January 1960			19 January 1960	
	Room Temp.	Cold	Room Temp.	Room Temp.	Cold	Room Temp.	Cold	Room Temp.
Pressure*	25°C	2–3°C	25°C	21°C	2–3°C	25°C	2–3°C	25°C
psia	1300 PST	1530 PST	1645 PST	1022 PST	1155 PST	1335 PST	1605 PST	
0.....	0	0	0	0	0	0	0	0
50.....	15.5	15.0+	15.5	15.5	15.0+	15.0+	15.0	15.0
100.....	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5
150.....	48.0–	48.0–	48.0–	48.0–	47.5	48.0	47.5	47.5
200.....	64.0	64.0–	64.0+	64.5–	64.0–	64.0–	63.5	63.0+
290.....	95.0	94.0+	95.0	95.0	94.0+	94.0+	94.0	94.0+

* The pressure gauge employed in this series was found to require recalibration, hence the pressure values given are not accurate.